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Electrification of Sugar Plantations*

By George L. Trist

The use of electricity for power and light has become so general on many plantations in late years that it is no longer an experiment. Cheaper first cost, flexibility and low maintenance costs are responsible to some extent for its rapid growth.

It is considered that 3-phase, 60-cycle, 440 volts is correct for the factory, stepping the voltage up in ratio to the length of transmission lines for outside installations.

In selecting the prime movers, a study should be made of the steam requirements in the boiling house, selecting a non-condensing unit capable of operating with good steam economy against the back pressure of the system. Providing the K. W. output of generator can be used, this unit should be of ample capacity to furnish the required amount of steam.

Additional units, if required, would be condensing, designed for best possible steam economy.

Exciters

One motor generator set of ample capacity to care for the entire station is preferred. There should also be one steam driven exciter set to care for the station in case of emergency, or to start up the station when all power is off with no outside supply.

Switchboards

No set rule can be applied in laying out the switchboard. Care should be taken that plenty of room be allowed for getting around and behind to make repairs to apparatus, reducing hazard of electric shocks to a minimum. Usually it is good practice to mount the field rheostats directly below or above the machine panels and oil circuit breakers about midway between panels and back wall, using remote control for operation. The panels should be not less than 6 ft. and preferably 8 ft. from the wall.

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

transformer rating. The initial cost is somewhat less than with a 3-transformer installation. With the 2 transformers, should one unit give out, the factory would have to be closed down until another transformer is secured, or the damaged one repaired. With 3 transformers, one can very easily be removed from the line and the factory still operate under reduced load until another is secured or the damaged one repaired.

General

The circuits from a power plant should be run in approved conduits to some centrally located point and distributed through fused safety switches in conduit to the various starters throughout the factory; all safety switches to be properly fused. These fuses are for feeder protection only, the overload relays taking care of the motors.

The following suggestions are made regarding installations:

All motors over 5 H. P. should be equipped with magnetic starters, overload relays, no voltage release and time limit acceleration.

Install all motor safety feeder switches and magnetic control panels in stations located as near load centers as possible. Install circuits from power plant to station bus bars in conduit and into safety switches. All the control panels being located in one room, it is a comparatively simple matter to connect from safety switches into the magnetic control panels. From the various central panels, the motor feeders should be run in conduit to the motors. The start and stop push button stations require very little space and can be located in almost any place in the factory convenient to the operators. Having the magnetic starters all located in one station has several advantages. The whole installation can be supervised by one man; the apparatus can be kept clean and free from moisture; hazard of electric shocks practically eliminated; possibility of unauthorized persons changing overload setting entirely eliminated.

Magnetic starters are used very successfully for remote control of Squirrel Cage or wound Rotor, reversing or non-reversing motors. With the control for Squirrel Cage motors, auto-transformers with several taps for reduced voltage starting are used with magnetic contactors for switching from start to run positions. Time limit acceleration is positive 15 to 25 seconds, according to motor service being allowed for motor to reach synchronous speed before switching from the start to run positions. With the magnetic starter, the possibility of the motors being thrown across the line before momentum has been gathered, resulting in blown feeder fuses, burnt contacts, possible danger to motors, belts, driven machinery, and high initial rush of current at power plant, is eliminated, and, incidentally, loss of production from careless or ignorant operation avoided. Also, it is impossible for the operator to keep starter in running position until starting coils are damaged.

Magnetic starters for wound Rotor motors, reversing or non-reversing, are furnished with 4 or 5 points resistance forward or reverse, grid type resistance being used. These starters have the same protective features as above. With the reversing type, it is impossible to throw the motor from full ahead to full reverse, when the operator throws the master controller from full forward to full

reverse, commonly termed "plugging" in crane service. The only thing that can happen is that the contactor on first point of resistance only closes and remains in this position until the high rush of current subsides when second point becomes operative, the motor stopping and reversing in reasonable time, no damage being inflicted on motors, driven machinery, or power plant. This control is excellent for overhead crane, runway table, or any severe reversing service.

Motor Driven Centrifugal Pump Installations

Pumping stations usually being located some distance from factory or power plant, a transmission line is necessary. The potential of the line being governed by its distance and load, however, step-down transformers for lighting and power are almost always necessary. The operating voltage would be governed entirely by conditions at the pumping plant. In large plants, the Squirrel Cage motors are objectionable on account of the large starting current taken from the line. The wound Rotor motor should then be considered.

In many installations, water is taken off at a much greater or less head than the equipment is designed for. This is a double error, and where at all possible should be avoided. Taking water off at increased heads, decreases the output, the motor not running at full load, which lowers the power factor. On the other hand, with heads decreased to any extent, while the output is increased, the efficiency of the apparatus is lowered, and the power cost increased. Should the motor not be designed to take care of this condition, there is danger of its being overloaded and damaged.

The wiring of pumping plants should be along the same general lines as the factory.

Each starter, however, should be furnished with integrating watt hour meters. In this manner, it is possible to determine the distribution of power over the system.

For domestic supply pumps with elevated tanks, magnetic control with float switch makes an excellent arrangement; when the water reaches the low level the motor starts automatically, stopping at the high level. In installations of this kind, overload relays and low voltage release for protecting the motors should be furnished; also a check or preferably a double check valve should be inserted in the discharge line. With installations of this kind, a continuous water supply is assured, water wastage from overflowing tanks eliminated, power costs and maintenance costs reduced. All the maintenance necessary is a few minutes of one man's time about once or twice a week to clean and oil the apparatus.

Lighting of Factory and Pumping Plants

Too much thought and study cannot be given to this problem. Good lighting, correctly distributed, with shades, reflectors and modern gas filled lamps, actually reduce current. The lighting cannot be too good. Plenty of light and better lighting result in better and more work, more satisfied organization and less accidents.

Three wire 220-110 volt feeders should be run in conduit from transformers into fused steel distributing boxes, conveniently placed throughout the factory. The number of circuits per panel would be determined by conditions. The feeders should be fused and distribute 2-wire 110 volts, care being taken to balance as near as possible the 3-wire system. Each circuit should be arranged to carry not more than 550 watts. Almost all factories require some lighting during daylight hours. These circuits should be arranged independently of night circuits, to eliminate unnecessary burning of lamps during daylight hours, increasing life hours of lamps, and saving in current.

Transmission Systems

Transmission lines vary with conditions; length of line, load, and potential desired must be considered. In laying out transmission lines on plantations, it is good practice to keep the line, if at all possible, out of cane fields. While burning off cane, the lines, hardware and insulators are often damaged. When the lines must pass through cane fields, consideration should be given the Bates steel poles, which are inexpensive, easy to erect and eliminate the possibility of total line destruction in the event of accidental fire with no prepared firebreak. The only objection to the steel pole is the fact that in the Islands, it is found very necessary to wire brush and paint them at least once each year to prevent rusting.

For general transmission purposes, butt treated cedar poles are favored.

Trouble has been experienced with burned cross arms and pole tops, where lines were running close to sea. This trouble was successfully overcome by bonding.

In erecting transmission lines, a good mechanical job should be insisted upon, care being given to depth of holes, and proper tamping of poles. Angle poles should be securely guyed.

Where transformers are installed, some approved fused cutout should be inserted in the primary lines.

The secondary from lighting transformers should be run 3-wire 220-110 volts with the neutral grounded at both ends.

Transmission lines should be provided with some suitable air switch so that the line can be disconnected from the system for making repairs, or in case of line trouble.

Transmission lines should be provided with approved type lightning arrestors. The cost is small against the protection afforded.

Plantation Camp Street Lighting

Where camps are located close to mill or power plant, series lighting controlled from the plant is the best arrangement. Where camps are widely scattered, the cost of the series system would be prohibitive. As an alternative to the series arrangement in outlying camps, where more than one lighting transformer is installed, a cheap multiple installation can be made by tying the third or neutral wire of all transformers together, necessitating the running of one only additional wire. This arrangement with time clocks gives good service. With only one

transformer available, the time clock is the only solution. The clock can be set for operation on or off at any time desired, eliminating the possibility of light burning during daylight hours.

Plantation Camp Metering

It is advisable to meter all camps in preference to establishing a flat rate system. It will be found that the power consumption with a metered system is very much less than with a flat rate system, because the user will be much more careful in his use of the current if he finds that careless usage increases his power bill.

Irrigation Pumping Equipment for Plantation Use*

By E. B. Devoy

Until very recent years the expenditure of any money for the improvement of plantation pumping equipment has been looked upon by most plantation executives as a very necessary evil. Efficiency in a pumping station was unheard of and the engineers, whose unhappy lot it was to try to convince the plantation managers that by spending money they could save more than they spent, had some very hard sledding. This state of affairs was not due to any animosity on the part of the managers but rather to the fact that it was difficult for them to see any tangible results after making the expenditures such as could be shown by spending money on the factories.

Today there are a few plantations whose pumping stations are in no better condition than they were 15 or 20 years ago, but the majority of the larger plantations have put their stations in a condition that is second to none on the mainland.

Steam Stations

The majority of steam stations in the Islands contain Riedler type pumps driven by Corliss engines, which range from simple to quadruple expansion condensing. Most of the pumps are what are known as the "Extended Type," having the water end located back of the steam cylinders, the plungers being driven by extensions of the piston rods through the back cylinder heads. This type of pump was the recognized standard until 1905 when the "Opposed Type" was first built. The extended type of pump permitted the use of ordinary power engines which were easily adapted to pumping engine work by extending the piston rods and did not necessitate the manufacture of special steam ends. It was not until 1909, however, that the advantages of the opposed type pumping engine were sufficiently recognized by water works engineers that the discontinuing of the manufacture of the extended type was justified.

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

As stated above, the extended type of pumping engine owed its popularity to the fact that it was a comparatively small matter to manufacture it by making slight changes in standard power engines, thus obviating the necessity of special steam engines for pumping work. This arrangement had several disadvantages. Power engines are designed for comparatively high piston speeds, but pumping engines necessarily operate at much lower speeds. The valve ports of higher speed units are large and frequently double ported, resulting in large clearance spaces. Owing to the higher speeds it was also necessary to use a much heavier type of steam valve gear and drive than would be required for a slow moving unit. Similar objections were met with in other parts of the steam engine; the bearings and pins were unnecessarily large and the weight was correspondingly increased. The arrangement of the water end tandem to the steam end requires the use of strut pieces between the steam cylinders and the plunger chambers, thus transmitting any expansion in the steam cylinders when hot to the water end and setting up unnecessary strains in the water end material. In Hawaii, a great many of these units are located some distance below ground level. On account of the great length of the extended type of pump its installation below ground level today would be prohibitive due to the high cost of labor, concrete pits, etc.

It was this high speed engine that was largely responsible for the popularity of the Riedler type water end. The Riedler valve with its mechanical closing device permitted quiet operation at a much higher piston speed than could be obtained with an automatic valve pump. The high speed, however, did not make a cheaper installation as the saving in small steam end was practically offset by the expensive Riedler water end. Of late years very few sales have been made of Riedler pumps, practically the only purchasers being the city of Chicago and the Solvay Process Company of Detroit.

Duty

While there are no figures available as to the original duty guarantee of these old pumps, it is conservative to say that on the compounds the duty ran from 110 million to 120 million foot pounds per 1,000 lbs. of steam and the triples from 120 million to 135 million foot pounds. The modern compound with 175 lbs. steam pressure and 75 degree superheat will show a duty of approximately 163 million foot pounds. A recent test made on a modern vertical triple expansion engine showed a duty of over 200 million foot pounds per 1,000 lbs. of steam. In the field of steam pumping machinery the trend toward higher steam pressures and temperatures has been along lines closely paralleling the development in large power installations. In addition to the improvement in economy due to increased pressures and temperatures, many of the later installations of reciprocating pumps are taking advantage of the gain due to the application of steam extracting feed water heaters to improve the overall economy. Stations sometimes find considerable difficulty in maintaining a proper feed water temperature. This situation is very satisfactorily taken care of by the use of a closed coil heater placed in the exhaust pipe and a second heater arranged to extract steam from the working charge in a receiver.

This will naturally give a lower duty per 1,000 lbs. of steam, but will increase the duty per million B. T. U.'s supplied, which in the final analysis is what the owner is directly interested in. Heaters of this type were installed on a vertical triple expansion engine in the Riverside Station of the city of Milwaukee. Tests were run with the heaters in service and out of service with the following results:

WITH HEATERS OUT OF SERVICE

Duty obtained, million foot pounds per 1,000 lbs. steam	205
Duty obtained, million foot lbs. per million B. T. U.'s supplied	173.5
Steam consumed per I. H. P. hour, lbs	9.16

WITH HEATERS IN SERVICE

Duty obtained, million foot lbs. per 1,000 lbs. steam	203.5
Duty obtained, million foot lbs. per million B. T. U.'s supplied	183.5
Steam consumed per I. H. P. hour, lbs	9.27

This shows with the heaters in service a loss of 1½ million foot pounds duty per 1,000 lbs. steam and a gain of 10 million foot pounds duty per million B. T. U.'s supplied.

Centrifugal Pumps

The subject of centrifugal pumps was very ably presented at the 1924 annual meeting of this Association, and it would be useless for the writer to try to improve on what has already been written. There are, however, a few points that may profitably be brought to the attention of the plantation engineers. In order that we may have a clearer understanding of the different types of centrifugal pumps the following definitions are given:

Rotary Pump: The rotary pump, while of a rotating type, is a displacement pump and should not be confused with the centrifugal type of pump.

Turbine Pump: A turbine type of centrifugal pump is one in which the impeller is surrounded by a diffuser containing diffusion vanes which reduce the velocity of the water leaving the impeller, transforming velocity head to pressure head.

Volute Pump: A volute type of centrifugal pump is one in which the transformation of velocity head to pressure head is taken care of by a spiral shaped casing instead of by using diffusion vanes.

Multi-stage: The multi-stage pump consists of a casing with two or more impellers placed in series on the same shaft. Multi-stage pumps are built either with or without diffusion vanes. In the multi-stage pump the water is forced from the discharge of one impeller to the suction of the next by means of reversing channels. These channels usually have directing vanes to guide the water and prevent its rotating.

Series Pump: By series pump is meant either one of two things. Either two single stage pumps are mounted on the one shaft with the prime mover, or there are two separate and distinct pumping units in series. In either case, the discharge line from the first pump serves as a suction line for the second.

Propeller or Screw: Propeller or screw pumps are similar to centrifugal pumps excepting that the flow of the water is axial instead of radial. These pumps are usually used for pumping a large volume of water at a low head. The efficiency of a screw pump is generally low.

Nozzles: The taper portions of the pump between the case proper and the discharge flange and the case and the suction flange are usually referred to as the discharge nozzle and suction nozzle respectively.

A centrifugal pump, due to its low initial cost, low maintenance and low operating expense makes an ideal installation where the head and capacity are constant. When an engineer finds it necessary to purchase a centrifugal pump, he will be well repaid if he devotes a little extra time in analyzing his requirements for head and capacity. This can be readily appreciated by bearing in mind that the pump manufacturer will design and build the pump to meet the engineer's specifications as to head and capacity, and it will be at this point that the pump will show the highest efficiency.

A single stage centrifugal pump is rarely built, except in the larger sizes, to deliver water to more than 200 feet head. The most remarkable exception to this is a 46.5 M. G. D. pump installed in Italy. This pump is delivering against a head of 498.6 feet with an efficiency of 81 per cent.

The idea of placing double suction single stage pumps in series is of comparatively recent origin. This arrangement usually gives a better overall efficiency than can be obtained with the multi-stage pump, although there are cases where the opposite is true. One of the most common sources of trouble experienced with the multi-stage pump is that caused by excessive thrust. This thrust is taken care of by several methods. Most pump manufacturers install in their multi-stage pumps a hydraulic balancing device. Some of these devices have proven successful while others have caused a great deal of grief to the operators. In other pumps the thrust is entirely taken care of by thrust bearings. Another method that is commonly employed is to "short circuit" a small amount of water from the last stage around to the suction side of the impeller. This, at first glance, would appear to be a source of great loss, but the additional work due to pumping this water will usually be far less than that necessary to overcome the friction of a thrust bearing. As the double suction pump is theoretically thrustless, troubles of this nature are practically eliminated in the series pump. It is sometimes necessary to install a high head pump in a pit that is too small to accommodate a series pump. If the depth of the pit is not too great, two pumps, with identical characteristics, may be installed in series, one in the pit and the other at the ground level. With this arrangement the discharge will remain the same and the head developed will be twice as much as with either one of them alone. You will also maintain the high efficiency for which the single stage double suction pump is noted. This method makes a very simple installation for an inexperienced operator, but it also has the disadvantage of decentralizing the units, thereby necessitating considerable traveling for the operator back and forth between pumps.

Centrifugal Pump Details

Plantation pumping equipment must be designed for heavy duty, especially on the plantations that have a very short rainy season. It is well, therefore, in ordering a centrifugal pump to embody such details in the specifications as will insure continuous service and will expedite repairs when necessary to shut down during the pumping season.

Some pump manufacturers recommend filling the base plate with concrete at the same time the grouting is put in. For a permanent installation this is a very commendable practice, but all pump manufacturers do not leave openings of sufficient area in the base to permit the pouring of concrete. If it is the engineer's desire to fill the base with concrete he should make mention in his specifications that base plate shall have openings of a certain minimum area.

When soft packing is used it is sometimes necessary to shut down to renew packing. The space between the stuffing box end and the bearing housing is usually so limited as to make the removal of the old packing a much longer operation than should be necessary. This work can be greatly expedited by specifying split packing glands. The engineer is then able to remove the gland entirely from the shaft, thus gaining space in which to work equivalent to the thickness of the gland. The material of which packing glands are made differs with the different manufacturers, but the majority of engineers agree that a bronze gland split horizontally is the best type of construction. It will also be well to specify that the ends of stuffing boxes are to be faced off at right angles to shaft. This not only facilitates the even setting up of the gland but will also permit the use of metallic packing at some future date when a satisfactory metallic packing is put on the market.

It would seem, from the various sizes that are furnished, that manufacturers of the split casing type of pump pay very little attention to the shape or size of the heads of capscrews that are used to hold the two casing halves together. During the pumping season it is sometimes necessary to open up a pump for examination or repair. There is nothing more exasperating at this time than to find that the open end wrenches which you assumed could be used for this work will only fit a few of the capscrews and that the rest must be removed with monkey wrenches, pipe wrenches or anything else available. The only remedy for this is to specify that all capscrew heads will fit a wrench of standard opening.

Gland cages or water seal rings, as they are commonly called, have a very important function to perform. Not nearly enough care is taken by the inexperienced operator to see that these rings maintain their proper position in the stuffing box. It is a very common practice during the pumping season, when the packing starts to leak excessively, to add another turn or two of packing to the outside of the stuffing box. Unless care is taken this method soon pushes the water seal ring past the sealing water opening thus destroying its usefulness. Trouble is sometimes experienced in removing these rings for repacking. If all manufacturers would follow the custom of some in making the rings in two halves, the necessity of sometimes removing the top half of pump casing in order to remove the water seal rings would be practically eliminated.

Pumping Station Accessories

By far the most important accessory to any pumping station is a measuring device for indicating or recording the pump discharge. A discharge measuring device is to a pumping station what a clinical thermometer is to a doctor. It is inconceivable why, at this modern day, many pumping stations are operating without any means of knowing what the pumps are delivering. Many stations depend entirely on the guess of a ditchman or reservoir man. One station that the writer has knowledge of has a weir located at the end of a long pipe line. The company went to considerable expense to install this weir, but they have made no provision to measure the water that is taken from this line at several points along its length to irrigate the fields it passes through. A properly constructed weir is admittedly the most accurate device known for measuring the flow of water in open channels. Its great disadvantage, however, when used in connection with pumping stations, lies in the fact that it must be placed at the end of the pump discharge line. This usually places it a long distance from the pump house, and unless unusual attention is given to noting the flow over the weir, a decrease in discharge may extend over a long period of time before being brought to the operator's attention.

The most satisfactory and easily installed device is the well known Venturi tube. Several different concerns manufacture indicating and recording instruments for use with the Venturi tube, all of whom claim different points in their favor. Probably the best known instrument in the Islands is the Type "M" Register, Indicator and Recorder, manufactured by the Builders Iron Foundry. These instruments when given the proper care and attention are probably as accurate as can be expected. It is advisable, however, that an indicating manometer be kept available for occasionally checking the accuracy of the recorder.

Gauges, both pressure and vacuum, are very essential instruments around a pumping station. From the difficulty experienced in purchasing a reliable gauge it would seem that such an article is not manufactured. For vacuum or low pressure work a manometer can be purchased at practically no increase in cost over a fairly reliable gauge, and when using a manometer the operator knows without any checking that his readings are correct, while if a Bourdon gauge is used a weekly check with a dead weight tester is necessary to insure a maintenance of accuracy.

A steam station requires several instruments not needed in a motor driven pumping station. A steam station should have a draft gauge on each boiler, a recording pressure gauge for boiler pressure, and a recording thermometer for feed water temperature showing the temperature of the water into and out of the economizer when an economizer is being used. There should also be a recording thermometer on the economizer showing the temperature of the flue gases leaving the boiler and after passing through the economizer. Many steam stations have revolution counters that are used for no other purpose than to decorate the gauge board. Without a revolution counter it is too easy a matter for a pump operator to speed the pump up a revolution or two when his discharge meter shows that for some reason or other the pump discharge has fallen off slightly.

A very satisfactory revolution counter for centrifugal pumps is one that is manufactured by S. A. Hasler, of Berne, Switzerland, and handled by C. H. Boulin, of New York City. This is a direct reading type of instrument with a range of 0 to 10,000 revolutions. One of these counters in use at Ewa Plantation shows after one year's service absolutely no wear or loss of accuracy.

Every plantation should have available some type of CO_2 indicator. In the ordinary steam pumping station there are so few boilers in service at a time that the installation of a CO_2 recorder is hardly justified. There are many types of hand manipulated gas analyzers which can be operated by any person of average intelligence, and the engineer in charge of pumping stations should make it a point to see that they are used regularly. The benefits derived from a periodic use of the analyzer will soon compensate for the labor required.

Records

During a recent visit to the mainland the writer was very much surprised at the lack of attention given to keeping accurate and complete records of pumping stations. This condition was found in both private and municipal pumping stations. One engineer in charge of several municipal pumping stations went so far as to say that after a pump was installed he never made any tests for efficiency. He stated that if they were in a hurry to furnish water they purchased and installed the best pump available and dispensed with the acceptance test, taking the manufacturer's test as satisfactory. When he was asked for permission to look over his system of keeping records, he replied that their records were so incomplete that nothing could be gained by an examination of same.

Due to the bookkeeping system in vogue on most of the plantations, it is practically impossible for the pump engineer to receive a detailed statement of his repair and operating expenses. He should, however, receive from the main office a monthly statement showing the total expenses incurred on each pump. The engineer should keep his own daily records of all mechanical repairs and all operating details, a monthly recapitulation being turned in to the main office to be incorporated in the monthly financial exhibit.

PUMPING STATION REPORTS

The following items are reported daily by the engineers on watch at each pumping station:

1. Steam (or Electric) Pumping Station No. .... Pump No. ....
*2. From 6 a. m. ...., 19....
*3. To 6 a. m. ...., 19....
4. Hours Pumping
5. Hours Stopped (Segregated into Time for Repairs and Adjustment or by Order)
6. R. P. M.
*7. Hours High Lift
8. Head in Feet
9. Suction in Feet
10. Venturi Meter Reading (6 a. m., 6 p. m. and 6 a. m.)
11. Gallons Water Pumped
12. Water Below Engine Center a. m. (and p. m.)

The items below apply to Steam Stations only:

13. Steam Pressure
14. Inches Vacuum
* 15. Temperature of Feed Water
16. Fuel Oil Meter
17. Inches Fuel Oil Used
18. Gallons of Fuel Oil Used
19. Height of Oil in Fuel Tanks
* 20. Draw Circle Around Boilers in Service.—No. 1.. No. 2.. No. 3..
* 21. Oil Car Received. No.... Inches in Dome....Degrees Temp....
* 22. Amount of Oil Received
* 23. Time Oil Car was Received
* 24. Time Oil Car was Emptied
25. Remarks

The items below apply to Electric Stations only:

13. Watt-hour Meter (6 a. m., 6 p. m., and 6 a. m.)
14. K. W. H. Consumption
15. A. C. Amperes
16. D. C. Amperes
17. D. C .Volts
18. Power Factor
19. Temp. of Motor, C
20. Temp. of Atmos. Corresp. to Motor, C
21. Remarks

With the exception of items marked with an * all of these items are transferred daily to a sheet designated "Monthly Record of Steam (or Electric) Pumping Station No. ...."

The items below appear on the bottom of each Monthly Record Sheet (Steam and Electric):

1. Total Hours per Month
2. Previous Hours
3. Hours to Date
4. Average Suction
5. Total Water Pumped

Steam Stations Monthly Record Sheets also include:

1. Bbls. Fuel on Hand on .... 1st ....
2. Bbls. Fuel received during month
3. Bbls. Fuel—total of above
4. Bbls. Fuel on hand on .... 1st ....
5. Bbls. Fuel consumed during month
6. Previous fuel consumption
7. Total to date

Equipment and repair records are kept on a 5″ x 8″ card index system. There is also a report sheet on which the pump operator is required to report any repair work done. The repair record is then transferred to the card index system for permanence.

A separate record is also kept in the pump office of all supplies issued to the different stations. There is also kept on a card system a personal record, giving a complete history of each employee.

Undoubtedly, some plantations keep a more complete system of records than others, and it is believed that a standard or uniform system, such as is employed in the sugar factories, would be of incalculable value in enabling the engineers of the different plantations to compare results.

Testing of Centrifugal Pumps

The Ewa Plantation Company has probably conducted more tests on centrifugal pumps than any other firm or plantation in the Islands. This has been

TESTED BY

EWA PLANTATION COMPANY, PUMP DEPARTMENT

EWA, HAWAII

TEST NO. 1-2

DATE March 17-24, 1924

TEST ON CENTRIFUGAL PUMP NO. 1

PUMP MANUFACTURED BY —

MOTOR MANUFACTURED BY —

PUMP DESIGNED FOR			MOTOR H. P.
M.G.D.	HEAD	R.P.M.	
12.0	70	695	200

RUN NO.	R. P. M.	SUCTION HEAD: INCHES VACUUM	SUCTION HEAD: LBS. PRESSURE	SUCTION HEAD: FEET	DISCHARGE HEAD: LBS. PRESSURE	DISCHARGE HEAD: FEET	DISTANCE BET. GAUGES	V. H. + −	TOTAL HEAD	M. G. D.	W. H. P.	W. H. METER TIME FOR 36 REV'S: MIN.	W. H. METER TIME FOR 36 REV'S: SEC.	AV W. H. METER TIME FOR 36 REV'S: MIN.	AV W. H. METER TIME FOR 36 REV'S: SEC.	EQUIV. H. P. INPUT	B H. P.	MOTOR EFFICIENCY	PUMP EFFICIENCY	GUARANTEED PUMP EFF.	
1	695	3.00		3.39	28.35	65.48	.66	−	69.53	11.925	145.51	2	25.1	2	25.1	191.56	174.31	91	83.4	82	75.9% Overall Eff.
												2	25.1								
2	696	2.05		2.917	28.5	65.83	.66'	−	68.81	12.1	146.12	2	26.2	2	26.2	190.12	173.0	91	84.4	82	76.8% Overall Eff.
												2	26.1								
												2	26.3								

REMARKS AND CONSTANTS

Previous to making run Number 1 no repairs or adjustments of any kind made on pump.

Before making run Number 2 pump was opened up and interior of casing scraped and painted.

K. W. Meter—Westinghouse.

K. T.—2400.

Transf. Ratio—12/1 and 20/1.

carried on mainly to maintain as nearly as possible the same pump efficiency as was obtained when the pump was installed. The testing of a motor driven centrifugal pump is a very simple proposition and requires but a very short time. There is, therefore, no reason why tests cannot be conducted at least twice a year; before shutting down for the rainy months and after the usual winter overhauling. Tests should always be made before accepting a pump to determine whether or not it meets the manufacturer's guarantee. In this connection, it is always well to request from the motor manufacturer a certified copy of the test of the motor that is furnished with the pump.

One of the greatest losses in a centrifugal pump, which increases with the length of service, is what is termed "Disk Friction." Disk friction increases as the surfaces become rougher. The friction of a smooth disk in a rough case is about the same as that of a rough disk in a smooth case. It has been proven that the shrouded type of impeller shows less disk friction than the open one and is in a small measure responsible for the better efficiency obtained with the closed runner type of pump. Engineers will find that by opening up their pump and scraping and painting the interior of the casing they will effect a considerable saving in power. It will also be well in the off-season to polish the impellers. It will usually be found that when the impeller is too badly pitted to polish the cost of a new impeller will be more than offset by the higher efficiency obtained with the new impeller. If a slight error in head was made when the pump was originally purchased, it can be rectified when the new impeller is ordered. This should also result in a more efficient unit.

When the plain type of wearing rings are employed a saving in power will usually result from the occasional installing of new rings. These rings are to reduce the leakage from the discharge to the suction side of the impeller, and in order to reduce the leakage to a minimum very close running fits must be maintained.

In the table is shown the result of two tests conducted on Pump No. 1 of the Ewa Plantation Company. The first test was conducted without improvements of any kind being made to the pump. Before making the second test the pump was opened up and the interior of the casing was scraped and given a coat of paint. The result was a 1 per cent improvement in pump efficiency. There is no question but what a further improvement could have been made if sufficient time had been allowed to remove and smooth up the surfaces of the impeller. The results of this test are given to show how easily it is sometimes possible to improve the efficiency of a centrifugal pump without going to any great expense.

A tentative draft of a Test Code for Centrifugal and Rotary Pumps appeared on pages 213-218 of the March, 1925, number of *Mechanical Engineering*. This draft is subject to correction and addition and when finally revised it is hoped will meet with the same popular approval as did the A. S. M. E. Boiler Construction Code. Operators of centrifugal pumps are urged to use this code as a basis in making and reporting tests.

In this article any preference as to steam or motor driven centrifugal pumps has been purposely omitted. It is obvious that for some services, certain types

of pumps due to service or structural reasons are best fitted. It is generally recognized, however, that the best pump for any service is the one that will do the work in the most satisfactory manner and for the least annual cost.

In closing, the writer wishes to thank W. H. Getz for steam pump data supplied.

Chemical Control in Cane Sugar Factories*

By H. A. Cook

In all chemical industries, that are operated on an efficient basis, there must be some method of control for all the reactions entering into the process. The reaction at which the process is most efficiently conducted may be acid, neutral or alkaline, but whatever the reaction, the best results are in nearly all cases obtained within a very narrow margin.

The control of the reaction of the juices going through the cane sugar house has undoubtedly been one of the most neglected and probably one of the least understood phases of the process.

The determination of sucrose or polarization entering the house in the form of mixed juice or cane, the per cent sucrose in the bagasse, in the clarified juice, in the press cake, in the sugar and in the final molasses has received considerable study and is on a fairly uniform and accurate basis. So also are most of the other methods of chemical control, although from time to time improvements are made in these methods.

In the fire room of the sugar house thermometers, pressure gauges and CO_2 recorders are vital for efficient control. Scales, venturimeters or electric meters have become a necessity for measuring the amount of fuel consumed. Scales are necessary to weigh the incoming cane, and are also necessary on the mixed juice tanks, at the molasses tanks and in the sugar warehouse. Thermometers and pressure gauges are a necessity on the juice heaters, on the evaporator effects and on the pans. So on, throughout the house, most of the methods of control have been brought to an accurate and scientific basis.

When the mill engineer speaks of the amount of fuel consumed, of the tons cane ground per hour, of the pressure on the rolls or of the amount of live or exhaust steam used, everyone understands the terms used and knows what he is talking about. If the sugar boiler speaks of the purity of the massecuite, of the amount of syrup or remelt taken into the strike, his language is understood. If the chemist speaks of the extraction, of the recovery or of the undetermined losses, everyone knows what he is talking about and usually sits up and takes notice.

All of these terms are intelligible and the methods of control are indicators of the efficiency of the operations. Everyone knows that in all cases the control must be held to a very close margin.

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

Without going into any of the details of the various theories of clarification which are advanced, there remains the fact that this very important phase of sugar making, the clarification and purification of cane juices, is dependent for a vital part of its efficiency upon the chemical aspect. The extent to which this is a chemical or physical process need not be argued, but it can be definitely stated that there should be a basis of control for the chemical side of this process. It might be argued that there has always been a basis and method of control for this side of the process; however, anyone familiar with the control in most cane sugar mills knows how indefinite this control has been.

For the control of the reaction of the clarification process litmus has been the indicator which has served as the basis of control for generations past. Litmus has served its purpose to the best of its ability, but just as many of our mechanical recorders have proven to be inefficient for their purpose, so has litmus proved to have limitations for its purpose.

In Hawaii, a large amount of investigational work on clarification problems has been conducted at the H. S. P. A. Experiment Station. These investigations have shed much light and given much information that heretofore has been obscure or has not been realized.

Work by McAllep and Bomonti (1) on the liming of juices for the best results in clarification gave positive evidence that there was a definite point in reaction at which best results were secured. It was demonstrated in this work that the phosphoric acid content of the juices was a vital element in the factor of clarification. It was shown that if the juice contained the requisite amount of this substance a good clarification could be secured provided the proper reaction was provided for this clarification. It was also found that the maximum increase in purity, for this method of clarification, was obtained at approximately the same reaction as that at which the optimum clarification was secured. This reaction was found to be neutral to or slightly alkaline to phenolphthalein. This investigational work gave the basis for a close control of the reaction of the juice at the liming station.

At the time of these investigations an instrument, or other material for the determination of pH values, was not available at the Experiment Station. This placed the control, for the time being, on the two indicators above mentioned, leaving a large range of reaction uncovered. It has since been demonstrated that a definite relation existed between this reaction and the hydrogen ion concentration or pH to which the juice was limed.

There was little, if any, definite information available as to the behavior of clarified juices during their course through the process, or when held for any length of time at high temperatures. There was no information as to the reaction changes which occurred when these juices were held at high temperatures over a shutdown period or for the length of time necessary in the settling tanks. It was recognized by many that a change in reaction did occur during such period, but as to how much or in what manner this might affect the operation of the plant little was known.

There was, and still is, a great difference in opinion among the authorities on cane sugar manufacture, as to what reaction a juice can be carried and be free from inversion during the course of the process.

The speed of inversion of sucrose in acid solutions has probably been studied more than the kinetics of any other reaction. The large amount of work that has been done in this connection has been confined almost entirely to the study of inversion of sucrose in acid solutions. There is still some conflict in opinion among the investigators as to the actual mechanism of the inversion process, whether 2, 4, 6 or more molecules of water take part in the reaction, just how the hydrogen ion combines in the reaction, or to what extent the reaction is influenced by the thermodynamic activities of the component reactants in the process. However, on one point there seems to be complete agreement, and that is, that the mechanism is a function of the hydrogen ion. Whether the hydrogen ion combines with the sucrose molecule to form a complex molecule which almost instantaneously reacts with water to form dextrose, plus fructose, plus hydrogen ion, or whether there is some other reaction is not agreed, but there is entire agreement to the fact that the reaction is a function of the activity of the hydrogen ion.

It is difficult to determine to what extent the theoretical considerations derived from a study of pure sucrose solutions can be applied to a complex composition such as mixed juice or clarified juice. In the former case the number of variables can be reduced to a minimum which cannot be done in the raw cane juice.

The lack of any such accurate knowledge and the conflicting opinions which existed on the subject prompted the Experiment Station to take up studies along this line.

Data published by McAllep and Bomonti (2) indicated that there is a quite definite reaction in terms of hydrogen ion concentration below which inversion, in detectable quantities, takes place in cane juices when held at high temperatures. This reaction was found to be considerably more alkaline than has been generally supposed to be the case. More comprehensive investigations have been completed by the writer (data soon to be published) that throw considerable additional light on this subject; the results found confirm those already noted.

Similar investigations have been conducted by Walton, McCalip and Hornberger, of the Carbohydrate Laboratory, Bureau of Chemistry (10). The reaction which they indicate as that at which inversion is detected is somewhat lower than found at this Station; however, this is due more to a different interpretation of the subject matter rather than to actual differences in experimental results. The results are in very close agreement with those found at the Experiment Station.

Unpublished data on the study of the rates of reaction changes in clarified juices at high temperatures show that there is a marked similarity in the reaction curves for different juices, although there may be quite a difference in the reaction rate in different juices. These results show that juices

become acid at much faster rates than is generally supposed. Little data is available to give any clew to the cause of this rapid development or increase in the hydrogen ion activity, although there is a wide difference in opinion. Whether it is due to decomposition of glucose in alkaline solutions or the decomposition of other substances, it seems apparent that there is development of an acid. There is a marked increase in the activity of the hydrogen ion, this activity increasing with increase in temperature.

All of these results show that there is need of just as close control of the reaction of the clarified juices as there is of the reaction of the juices at the liming station.

Another factor that at present makes imperative the reaction of the clarified juice as a basis of control is the apparent difference in the resulting reaction of different juices when limed to apparently the same reaction and subjected to the same conditions of temperature. It has been noted that there is a decided difference in the amount of drop in pH secured in different juices between the cold limed juice and the hot limed juice leaving the heaters. In some cases the drop in pH between the cold limed juice and the clarified juice is only from .2 to .3 pH, while in other cases a difference amounting to as much as .8 or .9 pH has been noted. Whether this difference is due to (1), slight differences in the initial pH of the cold juice; (2), to differences in the temperatures in the heaters, or (3), to inherent differences in the juice, has not yet been definitely determined.

These factors make it almost imperative that the reaction of the clarified juice be carefully controlled in order that inversion through the process be avoided.

The mention of inversion losses is often scoffed at, but it is now a recognized fact that inversion takes place in detectable amounts at much more alkaline reactions than has been generally supposed. If the resulting loss, which would accrue to a factory by the inversion of .1 per cent of sucrose in clarified juice, were calculated, the result would be surprising to many factory operators.

There will undoubtedly be developed, in the very near future, some means for the automatic control of the reaction of the juices in the sugar house on an hydrogen ion concentration basis. Such a control has already been developed in many industrial processes. Considerable experimental work has been done in this connection for sugar houses. One of the chief difficulties in this connection has been the development of a suitable electrode. The platinized hydrogen electrode is not suitable for this work. Some of the recent developments in the way of a continuous flow type electrode, constructed of tungsten or other material which will not poison in the presence of organic solutions, and the ability with their development to do away with hydrogen gas is a long step in this direction, but for the present, at least, this control will have to be maintained by some indirect method.

Steps were taken at the Experiment Station to meet this need of a definite and scientific basis of control of the reaction of juices in the mill. This work

resolved itself into finding a method, or adopting a method already in use, to meet conditions in Hawaii.

The use of available potentiometric methods is not adaptable to use in plantation laboratories. This is due not only to the cost of such equipment to individual plantations, and to the skill and care required for their use, but also to the inherent characteristics of the hydrogen electrode when used in organic solutions. These and other factors eliminating the use of potentiometric methods there remained the choice of some colorimetric method or the adaption thereof. The method of Clark and Lubs (3) using comparator tubes with buffer solutions, or the spot test method of Felton (4) as used and described by Brewster and Raines (5), or by Perkins (6), also using buffer solutions, did not seem to possess suitable characteristics for general use in Hawaii.

The main objection to most of these methods was the use of buffer solutions. It was at first found difficult to prepare buffer solutions having the values ascribed to them; these difficulties were previously described (7) and it was thought that this was due to inability to prepare chemicals of sufficient purity. The buffers so prepared required considerable readjustment. This difficulty was later found to be largely due to the inaccuracy of the instrument used in checking the values of these solutions. It was then found that accurate buffer solutions could be prepared if the proper care were exercised in their preparation. However, the preparation of such solutions requires considerable time and labor, as well as such facilities as are lacking in over 95 per cent of the plantation laboratories. It would be an endless undertaking for the Experiment Station to attempt to supply such solutions.

It was then found that buffer solutions could not be counted upon to retain their values for any length of time. Buffer solutions, with indicator added, sealed in sterilized comparator tubes, are supplied by commercial houses, but these are open to more or less the same objections. There are other methods such as that of Gillespie (8) and others by which pH values are determined without buffer solutions, but these methods were considered hardly applicable to plantation conditions.

As some colorimetric method seemed to be most feasible of adaptation, the alternative remained to produce color charts of standard color values. Color charts are procurable on the markets, but these charts do not give very satisfactory results when used in the comparison with such highly colored and often turbid solutions as mill juices. One reason for this seems to be a lack of sufficient concentration of indicator producing too light a color in the charts, while another is the lack of the liquid qualities required for easy comparison.

The preparation of standard color charts was undertaken at the Experiment Station. The object was to reproduce in some satisfactory manner the color changes produced by adding definite quantities of indicator to definite quantities of buffer solutions of known values. Considerable experimental work was required to determine the best indicators and the best concentration of indicator for use with cane juices.

A description of some of the details and some of the difficulties encountered by the Experiment Station in preparing and making available such a method for the plantations of the Islands may be of value to those interested in making available better methods of control for plantation laboratories. Perfection is by no means claimed for the method, but it is considered a valuable asset. As the Experiment Station is conducted for the mutual benefit of all of the Hawaiian plantations and does not participate in commercial work, the charts as developed by the Station and to be described, are available for distribution only among the plantations of the Islands. The amount of material prepared for this purpose was only sufficient for local distribution and replacement.

The indicators proposed by Clark and Lubs (3) were found most suitable, the concentration of indicator solution being the same except for phenol and cresol red which was changed from a .02 to .04 per cent solution. The most definite color changes were secured by using 4 drops of indicator to 1 cc. of solution.

Standard color charts had been prepared and were in use at Crockett refinery, but no data on the preparation or the materials used was available, so that the work at the Station had to proceed without the benefit of other experience. The work was greatly handicapped in that it was being carried out at such great distance from any satisfactory source of supply of materials.

The color changes of phenol and cresol red were first reproduced. These colors were made in oil on artist's canvas; very good colors were made in this manner, but they had the common fault of such colors, namely, lacking the brilliant liquid quality shown by the solutions from which they were prepared, thus making comparison quite difficult. Two serious errors were here committed; the effect of the glass to be used in covering the colors was not taken into consideration; this proved a much more serious factor than would at first appear, for the inherent color in the best grade of glass, procurable locally, considerably altered the colors; the second error was that a source of supply of a good grade of glass was not established, consequently different lots had a different effect on the colors.

About this time it was learned that the colors in use at Crockett were made from dyed celluloid. No data was available as to the process, as the work was done by an outside firm. Experiments were started on this line and proved a difficult task without any knowledge of dye stuffs or dye processes. Small quantities of material were finally produced covering the color range of phenol and cresol red.

The two errors made in the previous work were corrected. A supply of very satisfactory crystal glass had been secured. In order to further obviate any influence due to the glass the color matches were made upon the proper background and through the glass, that is, the dyed celluloid, when covered with glass, was brought to as near the desired color as possible. However, another error was committed in that the supply of celluloid and its composition was not investigated. When the local stock of material was exhausted, new supplies had to be located; these differed so much in texture, composition and

affinity for dye that the previous formulas would not produce anywhere near a similar color.

A new type of material was secured after considerable time and investigation which had many decided advantages over celluloid. This material took dye much more readily and without the use of a hot bath. This latter factor was a decided advantage, for the temperature of the dye bath was an important factor in dyeing celluloid. The bath had to be hot enough so that the dye would permeate the material, and yet guarded so that it did not become too hot resulting in the material turning opaque.

New formulas had to be worked out for this material, but with the experience already gained and the fine working quality of the new material, the colors for phenol and cresol red were duplicated in a small part of the original time.

About the time the second reproduction of these colors was completed a new Leeds Northrup potentiometer was secured by the department. After being installed and thoroughly checked it was found that the previous instrument was in error to the extent of from .2 to .3 pH and that the results obtained by the use of the standard colors were in error to the same extent. This necessitated a complete revision of the colors for these two indicators.

Standard colors were also made up for brom thymol and thymol blue which gives a very complete range for nearly all reactions encountered in the cane sugar house.

Many difficulties which are not here enumerated, were met with in the development of the method and the making of the standard charts. It was a matter of considerable difficulty to secure a supply and a source of supply of uniform reaction plates. Plates having depressions 7.5x20 mm. were required. Coors Porcelain Company is now making these plates. The indentations of the color reaction plates used in practice must be the same size as those from which the colors are prepared. Certain other conditions which are taken up in the instructions must be followed.

There is some justifiable criticism toward the use of any colorimetric method. There is in this method. The use of the potentiometer is far from being free from its limitations in this field. Several factors have arisen which have given considerable trouble in the use of these instruments. There is much yet to be learned in connection with the use of the hydrogen electrode (9).

Inasmuch as the buffer solutions are eliminated and the color charts are made the basis of the values, a certain personal element enters into the determination. Even in view of such limitations as may be inherent in the method, it is a big step in the right direction, and results can be secured that are very close to those secured by the use of the potentiometer.

This method has been in use in Hawaii only during part of the present grinding season; the charts have been distributed to between twenty-five and thirty plantations. Some of the chemists have taken up their use in a very serious manner and many interesting points in factory operation are being brought out by their use. It makes a very simple method for the reaction con-

trol besides making it possible to place the results of different factories on a comparable basis and in terms of expression comprehensible to all.

Where the method is used as a means of routine control irregularities in liming are immediately detected. It has shown that the liming practice of some factories is very regular while that of others is very irregular. As an instance of this, the results of one factory show that the liming can be held to within very narrow limits. At this factory, out of some 150 routine samples, there was a maximum variation of only .5 pH and only 12 of the samples varied to this extent. The method has in other instances showed up very irregular liming practices, as, at one factory the reaction of the clarified juices showed variations from pH 5.4 to 8.2. Many factories have greatly reduced the amount of undetermined losses by careful attention to the reaction of the juices going through the house.

A gain of .3 in purity in the clarified juices is credited to the use of the method by the chemist of one of the progressive plantations. This gain is due to the ability to maintain a much greater uniformity in the reaction of the juices. At this factory it is reported that at the beginning of the control less than 60 per cent of the juices were at the desired reaction. Within less than two weeks this percentage was brought up to 85, and very shortly over 95 per cent of the juices were maintained at the desired reaction. This one gain at this one plantation would more than pay all expenses of the investigational work in producing the charts and the cost of their production.

Another instance of economy gained by attention and application of experimental data is the cutting down of losses over shutdown periods. Many factories that have suffered severe losses over these periods and others that have been to considerable expense in the use of preservatives have been enabled to eliminate or materially reduce these losses and cut out the use of preservatives. This is accomplished by careful attention to the reaction and the temperature of the juices entering the settling tanks and the proper insulation of the tanks.

References

(1) The Hawaiian Planters' Record.
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Irrigation Water Seepage Losses*

By Joel B. Cox

If we think of a sugar plantation as a plant for transforming certain natural assets into a marketable product, raw sugar, its efficiency is measured by the extent to which these natural resources are utilized as against the wastage which they suffer. Of first importance among these natural resources are:

Labor,
Soil and its fertility,
Water,
Sunlight,
Atmospheric temperature, humidity, etc.,
Fertilizer.

It is water that we are now considering. All our irrigation water reaches the Islands in the form of rainfall, and as yet we have discovered no way of controlling either the amount or the time of its receipt. We may thus take this as the starting point of our study or the 100 per cent of maximum efficiency. From the time when it first reaches the surface in the form of rain, this water is subject to rapid and continuing depletion.

A part escapes to the sea in surface runoff, a part is re-evaporated from the ground surface, and a part transpired by the vegetation on drainage areas. Of the remainder, part disappears from the surface and through deep percolation reaches the ground water system, and another part is taken into our surface irrigation system for storage, transportation and eventual use in the fields. Of the ground water, much the greater fraction succeeds in percolating either to the sea or to that great body of brackish water which underlies the thin floating film of fresh ground water of which we can make use. So, evaporation and percolation have enormously depleted the supply from the rainfall before we ever get our hands fairly on it, either by diversion of surface streams or by pumping ground water, and when we think we have it, we find its powers of escape are by no means exhausted. It escapes from the beds of our reservoirs and ditches to an enormous and only too frequently unguessed amount, and the amount delivered at the margin of our fields is seldom over half that of our visible supply. Even after we start to apply it and turn it fairly into the field, our troubles are by no means over, for the slippery stuff pays no attention to the imaginary surface forming the lower boundary of the root zone of the cane, but persists in its downward path offering the cane rootlets only a bare chance to grab at it in passing. So, of all the water which falls in the form of rain, only a tiny and a rapidly vanish-

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ing fraction do we succeed in conducting to its point of usefulness, the absorbing rootlets of the cane.

But this tiny percentage is of the utmost importance, and in few parts of the world is water of higher value for agricultural purposes. About 50 per cent of the Hawaiian sugar crop is grown on plantations on which water is the limiting factor in production. On such plantations additional water is worth exactly what you can get for it, that is, the net value of the additional sugar produced by its use. This value is almost always very high. With ordinary prices of sugar, it will usually fall between $20. and $100. per million gallons of water delivered to the field. Even with the other plantations whose production is largely controlled by land area or other factors, if they irrigate at all, their water is worth to them what it costs to get it, and if all sources of expense are included this will often reach unexpectedly high figures. It is seldom that water on an irrigated plantation does not exceed in value $10. per million gallons at some time during the year.

We thus have the situation presented, of the very valuable physical substance, water, reaching the Islands in great profusion, freely and without price, and escaping with such ease and rapidity that we are eternally in want for it. Every bucketful we can save in the right place and the right time will increase our crops, our income and our prosperity by just so much. With enormous losses occurring all around us, the opportunities for preventing them with profit are many and varied, but the elusive character of the substance and the insidiousness of its wastage make the task one requiring painstaking care, constant vigilance and high skill.

It will help at this point to consider a case of the utilization of the rainfall from a single Hawaiian watershed, which has been somewhat completely measured. We can here determine the relative magnitude of the various losses it suffers and find the points of attack on the problem of its conservation which offer the greatest opportunity for economic success.

The upper watershed of the Wahiawa Stream on Kauai has a drainage area of 2.64 square miles and a mean annual rainfall of 170 inches. The average runoff is 10.7 million gallons per day or almost exactly 50 per cent of the rainfall. Of this amount 77 per cent is diverted for plantation use, a very high percentage, made possible by large storage facilities on the plantation and an intense demand for water. Of the 85 inches which disappear from the surface probably half is evaporated and transpired, though this figure is highly uncertain. Using this figure for the entire drainage area above our pumps, we find that we are recovering from wells and tunnels about 15 per cent of the total underground flow. The losses in the plantation ditch and reservoir system are measured and we may form the following water balance sheet, showing the final destination of the rainfall from this watershed:

TABLE 1

Part of System	Per cent water lost in terms of that entering	Per cent lost in terms of total amount	Balance retained per cent of total amount
Watershed transpiration and evaporation.........	25.0	25.0	....
Floods to sea..................................	11.5	11.5	....
Deep percolation	25.0	25.0	....
	61.5	61.5	38.5
Recovery by pumping..........................	15.0	3.8	42.3
Seepage in diversion ditches.....................	6.0	2.3	40.0
Evaporation and seepage in reservoirs............	24.0	8.7	31.3
Seepage from main distributing ditches..........	20.0	6.26	25.04
Seepage from field ditches.......................	20.0	5.01	20.03
Losses in watercourses and heads of rows by W. P. Alexander, H. W. Baldwin..................	50.0 estimate	10.02	10.01
Loss by deep percolation under rows..............	35.0 estimate	3.51	6.50

At this point we are ready to deliver our water to the roots of the cane. What they do with it is another problem.

We thus have 14 parts of the rainfall lost to one delivered, although the watershed is very completely developed both by storage and by pumping. The percolation losses as found for this particular watershed are by no means excessive as compared to the usual Hawaiian conditions, so far as my data show.

In considering the above table from the standpoint of an attempt to recover a part of the lost water, we find:

Transpiration, evaporation and percolation from the watershed are unapproachable by any means in current use.

Floods to the sea can be reduced by the construction of reservoirs, which is not our problem of today.

The amount recoverable by pumps can often be increased with sufficient knowledge of the rates and directions of flow of the subterranean waters, and this is intimately connected with the special subject we have in hand.

The seepage losses from ditches are large in total amounts and perhaps most easily controlled of all. Lining the ditches with an impervious material, and location to avoid pervious strata and to give cross sections of low leakage are the most promising methods.

Seepage losses from reservoirs are of great importance where the water is stored for several months, and their reduction frequently offers a field for profitable work.

Losses after reaching the field are more the province of the agriculturist than the engineer, though we can perhaps help out with measurements and data on the various soils which are encountered.

Evaporation losses from reservoirs are uncontrollable except in so far as we may alter the shape and depth of the reservoir. Except in the fortunate case where the reservoir is resting on a permanent ground water table, the evaporation losses are apt to be enormously surpassed by the seepage losses in the average Hawaiian soil.

The prevention of seepage losses from reservoirs and ditches offers, therefore, the most likely zone of profitable work for the engineer and it is to help answer the questions of where and how to locate, and when and how to line that the data of this paper are offered.

The crux of the question of water conservation is accurate measurement. It is usually not the losses which can be seen but those which are invisible that are most costly. If your men on the plantation are even mildly interested in their work, the leaky flume or gate, or the section of ditch with visibly loose banks and with springs appearing below it, will be recognized and repaired. It is the imperceptible underground losses which mount so rapidly into staggering totals. These can only be located by careful measurement. Furthermore the whole problem is fundamentally one of economics. Of course, we could reduce losses to a minimum by lining all our reservoirs with concrete and conveying our water in pipes or concrete lined canals. We could at the same time and in the same way send most of our plantations into the bankruptcy court. We cannot afford to spend two cents for ditch lining unless it will return us more than two cents in increased sugar sold. We must first know exactly where and how much water is being lost, then what it is worth if saved, and lastly, what it will cost to save it. Only if we have reliable knowledge on all three points can we hope to make money through a campaign of seepage reduction.

I do not intend to give much on methods of measurement. That would require a paper in itself. The determination of seepage is done by finding the difference between the amount of water flowing into the section under consideration and that flowing out of it. Any satisfactory method for the measurement of flowing water will do. Weir measurement by a standard weir is the most accurate method available, but is rarely feasible. The current meter is therefore the fundamental tool for most work. The various types of proportional flow and propeller meters on the market are very similar to the current meter in principle, though they differ in their application. The first great difficulty in the accurate determination of seepage is the fact that it must be fixed by the difference between two measurements. Thus, if the loss which is to be measured is 10 per cent of the total flow and each measurement is subject to an uncertainty of 5 per cent, your determination may vary widely from the truth. The second difficulty is that in plantation work a steady flow or continuous condition is rarely met with, and actual losses can usually be obtained only by a series of measurements of considerable length, obtained only by a good deal of labor. The

only point in the operation of the current meter that I care to bring out is that its use is an operation requiring knack and a kind of horse sense in regard to water and its movements that are the result of experience rather than technical ability. The poor quality of the average gaging by a young technical graduate is as marked as the excellent quality of the work of a well taught Japanese of no education. With the latter, however, the required accuracy can be maintained only with systematic checking. It is this which renders it possible to get your data rather cheaply.

Aside from the measurement of losses, as indicated above, is the experimental determination of rates of percolation through various materials. Two methods of testing have been developed. A field test of great utility is to drive as long a section of pipe into the ground as you can; sharpen with a bevel on the outside and drive with any simple hand pile driver rig that can be easily

Fig 1.

arranged. Fill it full of water and observe the subsidence of the column, being careful to keep your rainfall. A laboratory test that gives more rapid and complete results for a wide variation of pressures is to use a pressure cylinder such as that illustrated in Fig. 1. This has the disadvantage that the amount of packing that the material receives is artificially controlled. It is of special value in selecting materials for dam construction.

We are now ready for a presentation of actual figures on the rates of percolation through various soils.

Table 2

TEST VALUE OF PERCOLATION COEFFICIENT

	Values of K in feet per day
Ashokan Dam (page 207 Waterworks Handbook)—	
No. 7 class B earth at 40 lbs. per sq. in.	0.264
No. 2 class A earth at 40 lbs. per sq. in.	0.031
No. 14 very fine sand and clay	27.3
Peahi Reservoir, Maui—	
Loose talus	20.0
Decomposed rock	3.4
" "	2.9
Soft, sandy pukapuka rock	1.44
Hard yellow soil	0.245
Natural pool in decomposed rock	0.25
Weathered talus	0.08
Tamped Soil for Dam—	
Black large grained surface soil tamped dry	1.09
" " " " " puddled	0.008
Red surface under soil tamped dry	0.68
" " " " " "	0.007
Yellow hard pan tamped dry	0.06
Purple soil (clay)	0.01
" " "	0.010
Makawao Reservoir Sites—	
Red clay	0.001
" " above Makawao	0.027
" " mixture	0.123
Semi loam	2.48
Loam	0.72
Light brown soil on slope	6.1
Fine brown loam	2.2
Gravel bottom	38.9
Hard yellow brown soil surface 3 ft. down	2.91
Reservoir (Kauai)—	
Bottom silt	0.003
Bottom rock	0.4
Red soil	0.9
By total loss test	0.083
Reservoir (Kauai)—	
Silt	0.004
Red soil	0.004
By total loss test	0.01
Reservoir (Kauai)—	
Brown bottom soil	0.0030
Loose large grained red brown soil	0.0006
Typical red brown soil	0.0019
Red clay from rotten rock	0.0015

Wahiawa Reservoir—	
Top of ridge red brown clay	0.00075
Slope blackish soil	0.00169
Pali brownish black	0.00087
Valley bottom	0.0015
Nuuanu Reservoir No. 4—	
3.57 in. 55 ft. deep clay assume saturation 20 ft	0.08
Reddish clay subsoils pressure test	0.03
Kauai—	
Pressure test	0.08
" "	0.09
" "	0.10
" "	0.11
Tamped moist	0.12
" "	0.12
" "	0.12
" "	0.13
" "	0.05
" "	0.05
" "	0.04
" "	0.05
" "	0.03
" "	0.04
" "	0.03
" "	0.01
Same lightly tamped dry	0.46
Scarcely tamped	2.55

Table 3

SEEPAGE LOSSES FROM RESERVOIRS

Reservoir	Depth of water feet	Loss Feet per day	M. G. per day	Per cent per month	Value of K feet
2	31	0.01	0.03	2.6	0.004
21	34	0.152	0.427	24.3	0.08
1	22	0.176	0.96	36.	0.10
1	27	0.322	1.99	46.	0.16
4	27	0.33	0.33	34.	0.16
5	25	0.26	0.6	53.	0.13
8	45	0.25	1.6	30.	0.12

Table 4

SEEPAGE LOSS IN SELECTED HAWAIIAN DITCHES

No.	Location	Material and notes on construction	Length of section ft.	Flow M. G. day	Loss Per cent per mile	Loss Ft. per day K
1	Maui	Best section of large open ditch in average soil	4,000	20	0.5	0.20
2	"	Average for same ditch	32,970	20	4.6	1.94
3	"	Open ditch thinner banks	20,000	40	3.17	2.92
4	"	A poor section of open ditch in ordinary soil	3,770	17	9.1	3.35
5	"	A large well built ditch, largely in tunnel	20,000	20	7.63	3.87
6	"	Dry country, porous rock, tunnels	30,000	30	5.28	4.86
7	"	Surface soil in watersheds, an old open ditch with poor banks	20,000	15	14.96	7.13
8	Kauai	Tight, fine grained red soil, open ditch, small flow in bottom of old ditch	3,500	4	....	.....
9	"	Same	8,400	5	1.9	0.034
10	"	Small flow in bottom of old ditch in rockier soil than the preceding	3,500	3	3.9	0.043
11	"	Old ditch in fine red soil	9,000	1.9	3.7	0.07
12	"	Old ditch in fine soil, some rocks	4,800	5.4	1.4	0.28
13	"	Same ditch as No. 8	3,000	18.5	4.0	1.67
14	"	Small ditch in porous brown soil	3,600	0.2	86.0	2.11
15	"	Average soil open ditch	15,000	19	6.45	2.88
16	"	Open ditch around volcanic cone, coarse, scoriaceous material	6,200	10	8.3	2.98
17	"	Red soil with many rocks	3,600	14	9.31	3.14
18	"	Coarse, dark soil	6,600	6.4	11.2	3.65
19	"	Small ditch used inter in granular dark soil	1,900	0.5	72.0	4.67
20	"	Same	4,300	5.0	38.0	7.00
21	"	Loose scoriaceous material in side of cone	50	5.0	....	32.00

Table 5

LOSS OF WATER IN CANALS NOT AFFECTED BY THE RISE OF GROUND WATER (Etcheverry)

Character of material	Feet per 24 hours
Impervious clay loam	0.25-0.35
Medium clay loam underlaid with hard pan at depth of not over 2 to 3 feet below bed	0.35-0.50
Ordinary clay loam, silt soil or lava ash loam	0.50-0.75
Gravelly clay loam or sandy clay loam, cemented gravel, sand and clay	0.75-1.00
Sandy loam	1.00-1.50
Loose sandy soils	1.50-1.75
Gravelly sandy soils	2.00-2.50
Porous gravelly soils	2.50-3.00
Very gravelly soils	3.00-6.00

TABLE 6

RATES OF PERCOLATION IN CANE FIELDS

	K feet per day
Freshly plowed plant field, just after planting, fine grained red soil.......	0.73
Same soil, third ratoon, very hard and solid............................	0.03
Fine grained brown soil, plant field, 5 months old, bottom of level ditch....	0.015
Red clay soil, plant field, 6 months old..................................	0.006
Red clay soil, ratoon field, 8 years old..................................	0.011

These figures are given, not to relieve anyone of the task of measuring his seepage before planning construction to eliminate it, but rather to encourage the getting of such data. Each ditch or reservoir, and even each section of ditch or small area of reservoir bottom, is a problem of its own and the variation in rates of seepage is so great as to require great caution in the use of general figures. They have a real function to serve, however, in crystallizing our experience, leading us to a general idea of what rates of seepage to expect and how various possible combinations of depth, degree of saturation and area of exposed surface will affect the rate of percolation. The units in which we measure seepage losses are of great importance. It may be proved experimentally that the rate of percolation through soils varies directly with the hydraulic gradient, directly as the square of the effective size of the grains (in the case of sandy material) and exhibits a large temperature effect usually given by $\frac{\times + 10^\circ}{60^\circ}$, where $\times$ is the temperature Fahrenheit. For ordinary use, then, the best coefficient for the rate of seepage is the depth in feet of solid water which will flow through a cylinder of soil of constant cross section in which the hydraulic gradient is unity, and at a standard temperature. In my data the temperature was seldom measured and may be taken as 75°.

The hydraulic gradient is sometimes difficult to measure. If a reservoir is suddenly filled and the ground is dry, the gradient is infinity and it remains high for sometime, until the soil surrounding becomes thoroughly saturated. If the ground water is at a great depth below the reservoir, the area is great and the percolation is, hence, sensibly vertical, and the gradient will approach unity as its limit. If the ground water is not so far down and the underground flow must take a flatter slope in order to escape, the gradient may be quite low. In the case of ditches, the gradient will ordinarily be considerably above unity. My measurements indicate that in the absence of other data a gradient of 1.75 may be taken for both reservoirs and ditches.

If we have measured and analyzed the seepage losses on a plantation, the next consideration is how best to reduce them. We may classify our efforts as:

1. Choosing tight reservoirs for our storage as far as possible, and adjusting our storage between existing reservoirs so as to give a minimum of loss.

2. Regulating our pumping ground water levels so as to lose as little fresh ground water as possible.

3. Locating unlined ditches in as tight material as possible.
4. Lining ditches and occasionally reservoirs.

In addition there is the possibility that in cooperation with agriculturists we may work out a practical method in certain soils of reducing the leakage away from the cane root zone by the intentional formation of semi-impervious plow pans, low in the root zone.

The only method of prevention on which we as yet have definite figures is that of ditch lining.

The only successful linings with which I am acquainted are:

Sheet steel,
Wooden planks or staves,
Masonry,
Asphaltic material,
Clay puddle.

For Hawaiian conditions, the first two are usually unduly expensive, and the last two, uncertain and unreliable. Masonry in the form of cut stone set with Portland cement mortar or of concrete holds the field of provedly successful use to the exclusion of all else. My cost data will refer then to this class of construction.

TABLE 7

COST DATA ON DITCH LINING

Description of ditch and lining	Thickness of lining	Cost Per sq. ft. cents	Cost Per cu. yd. dollars
Tunnels in mountains, large size, very expensive transportation, 1921	4" minimum	87.6	51.60
Same, less expensive transportation, 1922	4" minimum	51.9	30.60
Cut stone in concrete backing, Portland cement pointing, 1922	6"	45.3	24.50
Cut stone, pointed but not backed	5"	20.0	13.00
Small ditch, concrete lining, difficult transportation, 1924	3"	28.7	31.00
Small ditch, fairly easy transportation	3"	25.0	27.00

California practice is to use a much thinner lining. Concrete down to 1½" in thickness and plaster about 1" are much used. Our own experience with the thin plaster linings has been anything but satisfactory.

The cost of such a lining will depend more than anything else on the accessibility of the work. With cheap rock and sand and not much trimming of the ditch bank to be done, the cost might be as low as 12 cents per square foot. Under unfavorable conditions, it might be three times this figure.

My present belief is that a thickness of 2½" of concrete with proportions about 1:2:3 laid without forms on side sloped of 1:1 is the most generally satisfactory and applicable of the various types which have been tried in the Islands.

The last, and in many ways the most important portion of this study, is in the economics of lining. In every case we propose to save a certain quantity

of irrigation water each year by constructing and maintaining a certain amount of lining. We must estimate:

1. The quantity of seepage to be recovered.
2. The value per million gallons of this water.
3. The annual value of the seepage recovered.
4. The first cost of the required lining.
5. The annual cost of the lining.

If the annual cost of the lining is found to be less than the annual value of the water saved, the work is justified, otherwise not. The easiest way to grasp the principles involved is to consider the computations for a representative case. Afterwards we can outline a few general relationships between the elements of the problem.

Let us assume a plantation on which the water saved will be used for more intensive irrigation on the same area. Let us have average cost records which may be subdivided as follows:

TABLE 8

Item	Present cost of production per ton sugar	Increase in cost of production for each additional ton of sugar from the same area
Clearing, plowing, preparing and planting	$ 6.00	....
Water	5.00	$ 2.00
Cultivation	12.00	10.00
Fertilizing	13.00	8.00
Harvesting	10.00	8.00
Manufacturing	10.00	8.00
Marketing	9.00	9.00
Depreciation	8.00	1.00
Sanitation, repairs and other overhead	12.00	2.00
	$85.00	$48.00

If we estimate the future price of sugar at 5 cents per pound or $100.00 per ton, each additional ton of sugar which is produced will net $100.00 less $48.00 equals $52.00 under the assumed conditions.

If, now, our overall duty of water for the assumed plantation plots is as shown in Fig. 2, we are prepared to compute the value of the water which it proposed to save. Let us assume that the average rate of application is 6 m. g. per acre per crop, equivalent to 22 irrigations of 10 inches each. This is at the point A in Fig. 2. At this point the slope of the curve, shown by the dashed line in the diagram, is 0.85 ton of sugar for each million gallons of water applied. The value of each million gallons is therefore 0.85 $\times$ $52 = $44. Let us next consider a section of ditch which carried water during 10 hours a day for 300 days in the year, in which measurements show a loss at the rate of 0.50 foot per

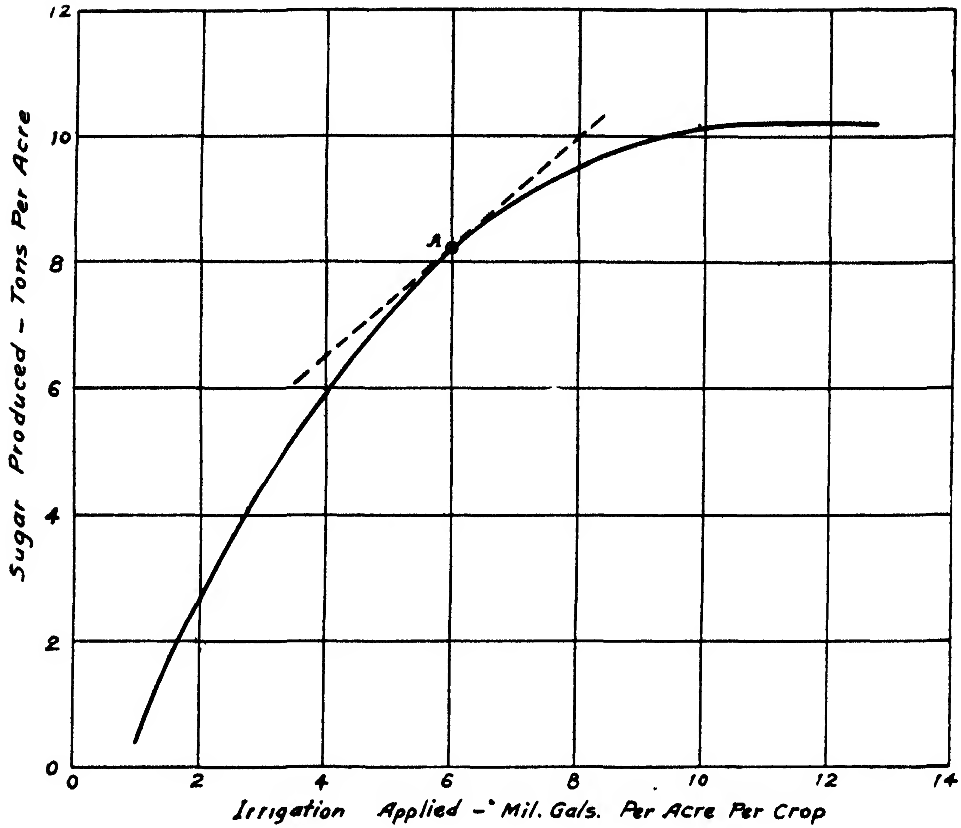

Fig. 2.

24 hours. To line this with concrete is estimated to cost 20 cents per square foot. Taking as a unit 100 square feet of ditch, wetted surface, the loss per year is:

$$100 \text{ sq. ft.} \times 0.50 \text{ ft.} \times \frac{10}{24} \times 300 = 6250 \text{ cu. ft. per year} = 0.0468 \text{ million}$$

gallon per year. $0.0468 \times \$44 = \$2.06$ per year annual value of the water lost.

The annual cost of the lining is computed as follows:

First cost $\$0.20 \times 100 = \$20.00$ per 100 sq. ft.

Annual cost:

Interest	7%
Depreciation	4%
Repairs and maintenance.............	2%
Taxes, etc...........................	2%
	15% on $20.00 = $3.00

The lining in this case is therefore not justified. It would pay for itself if the leakage saved were at the rate of 0.73 foot in 24 hours.

In general, if

V = Value of water per million gallons;
H = Number of hours per day that water is in ditch;
D = Number of days in year that water is in ditch;
K = Rate of percolation in feet of water surface in 24 hours;
C = Cost of lining in cents per square foot;
P = Annual rate of charge on first cost of lining in per cent.

The condition that the value of water saved first pays for the lining is given by:

$$320\frac{CP}{HDK}$$

Table 9
Cost per Million Gallons
of
Water Saved by Ditch Lining
C = Cost of Lining = 25¢ per sq. ft
P = Annual Charge = 15 %

Seepage Saved in feet Per day K	Time Ditch is Holding Water in Hours per Year							
	500	1000	2000	3000	3650	4800	7200	8760
0.05		$2400	$1200	$800	$658	$500	$333	274
0.10		1200	600	400	329	250	167	137
0.15		800	400	267	219	167	111	91
0.20		600	300	200	164	125	83	68
0.25		480	240	160	132	100	67	55
0.30	$800	400	200	133	110	83	56	46
0.4	600	300	150	100	82	62	42	34
0.5	480	240	120	80	66	50	33	27
0.6	400	200	100	67	55	42	28	23
0.7	343	172	86	57	47	36	24	20
0.8	300	150	75	50	41	31	21	17
0.9	267	133	67	44	37	28	18	15
1.0	240	120	60	40	33	25	16.67	13.70
2.0	120	60	30	20	16	12.50	8.33	6.80
3.0	80	40	20	13	11	8.33	5.55	4.56
5.0	48	24	12	8	6	5.00	3.33	2.74
	$40	$20	$10	$5				

Table 9 is based on cost of lining at 25 cents per square foot and an annual charge equal to 15 per cent of the first cost. The heavy zigzag lines indicate the limits to which we can afford to line with water worth $5.00, $10.00, $20.00 and $40.00 per million gallons. Summarizing this table in the light of our study of losses in existing ditches (Tables 4 and 5), we see that with ditches which run both night and day throughout the year, most ditches require lining even though the water is not especially valuable. For ditches running 2,000 or 3,000 hours per year, with high water values, the average ditch will require lining, while low values of water would need excessive seepage rates to pay for themselves. The more occasional ditches will ordinarily be lined only when the seepage rate is unusually high and water valuable.

It may be safely predicted that on nearly every irrigated plantation there are few investments which will yield greater returns than ditch lining. It should be done systematically and carefully, and a program of work adopted based on careful measurements so that the heaviest losses shall be the first controlled. The field of reservoir lining is also promising, though the rates of percolation are usually lower here. One point to remember is that other things being equal it pays to line the ditches nearest the field first. To start at the intake end means that much of the water you save is relost in passing through the leaky ditches further along the line. A large field for research is offered in the determination of seepage losses. One particular phase which needs much more work done upon it is the determination of the probable seepage loss from a reservoir basin in advance of its construction. Something can now be done by means of the tests I have described, and I believe the fullest investigation possible should be made in every case before a cent is spent in dam construction. The development of more comprehensive methods which will decrease the margin of error of our estimates of seepage is urgently needed. The aggregate amount of money which has been wasted in Hawaii in reservoirs which will not hold water would have served to pay many additional dividends.

Report of the Committee on the Relation of Cane Diseases to Cane Varieties*

By H. Atherton Lee

These Islands are very fortunate in having but few of the infectious cane diseases which are known in other countries. In countries of the Old World particularly, such as India, Java, Formosa, the Philippines, New Guinea and Australia, where cane has been grown for centuries, a number of infectious diseases occur which are not present here as yet.

In a number of these other countries, our commercially grown varieties, H 109, Yellow Caledonia, D 1135, Lahaina, Uba and Badila have been grown

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under conditions where they were exposed to some of these foreign diseases. It has seemed to this committee that a record of the reaction of such varieties to these foreign diseases would be valuable in the event of the introduction of any of these new diseases to these Islands. A knowledge of the extreme susceptibility of some of our most widely planted varieties also may increase our vigilance in keeping such diseases out. Our Tip canes do not seem to have been grown to any extent in other countries, so that there is little or no knowledge concerning their reaction to foreign cane diseases. A record of the susceptibility of our standard varieties and some of our new seedling varieties to local diseases is also tabulated and may point the direction for some of the breeding work and field administration on the plantations.

In the tabulation we have included two columns, in the first the susceptibility to infection, or, in other words, the readiness with which the variety contracts the disease. In the second column is the degree of tolerance, or, in other words, the degree of injury suffered from the disease. The word immune is used here to indicate total ability to resist infection; a cane immune to a disease is incapable of contracting the disease. The term resistant, as we use it here, indicates that the cane seldom is affected, although infection is possible. It may mean also that once the cane is infected it suffers little from such infection. The knowledge concerning the reaction of the varieties listed to these diseases is either from personal experience or, in some cases, from the literature of other cane countries.

TABLE I

The Susceptibility or Resistance of H 109 to Infectious Foreign Cane Diseases [1]

Name of the disease	Causal Agent	Distribution	Susceptibility to infection	Degree of injury after infection
Fiji disease	Unknown	Fiji, Australia, New Guinea, the Philippines	Severe	Severe
Gumming disease	*Phytomonas* (*Bacterium*) *vascularа*	Fiji, Australia, Mauritius, Brazil, Porto Rico	Severe	Severe
Leaf scald	A bacterial organism unnamed as yet	Java, the Philippines, Australia, Fiji	Severe	Severe
Bulaclac	A flowering parasite like a mistletoe, *Aeginetia indica*	China, the Philippines, and Malayan region in general	Unknown	Unknown
Sereh	Unknown	Java and Formosa	Unknown	Unknown
Streak disease	Unknown; suspected of being a filtrable virus	Natal, South Africa	Unknown	Unknown
Downy mildew	A fungus, *Sclerospora sacchari*	Australia, Formosa, the Philippines, Fiji	Moderate	Slight
Cane smut	A fungus, *Ustilago sacchari*	India, Java, the Philippines, China; reported from several other countries but needs corroboration	Resistant	Resistant

Pokkah bong	Unknown	Java, the Philippines	Unknown	Unknown
Curly top (possibly Pokkah bong)	Unknown	Australia	Unknown	Unknown
Wilt	A fungus, *Cephalosporium sacchari*	India, the Philippines and South Africa	Unknown	Unknown
Collar rot	A fungus, *Hendersonia sacchari*	India	Unknown	Unknown
Polvillo	Unknown	Brazil, the Argentine	Unknown	Unknown
Dry top rot	A fungus, *Plasmodiophora vascularum*	Porto Rico	Unknown	Unknown
Rust	A fungus, *Puccinia kuehnii*	Java, the Philippines, Formosa, Australia, India	Slight	Resistant
Yellow leaf spot	A fungus, *Cercospora kopkei*	Java, the Philippines, Reunion, the Argentine	Slight	Resistant
Banded sclerotial leaf disease	A fungus, unnamed, with sterile mycelium	India, the Philippines, Java	Moderate	Moderate
Red leaf spot	A fungus, *Eriosphaeria sacchari*	Java	Unknown	Unknown
Brown spot	A fungus, *Cercospora longipes*	India, Porto Rico, Trinidad	Unknown	Unknown
Black leaf spot	A fungus, *Phyllachora sacchari*	Java, the Philippines	Unknown	Unknown
Pestalozzia leaf spot	A fungus, *Pestalozzia fuscescens*	Java, the Philippines	Unknown	Unknown

In the foregoing table have been listed several diseases of which we have no knowledge concerning their effect on H 109; such diseases have been listed in the table to show the number of infectious troubles which have not yet become established in Hawaii. A great many diseases which seemed of minor importance have been omitted from the list. A top rot described from Java and another from Australia have not been included in this list, since knowledge of their infectious nature is not known to us here in Hawaii.

From the foregoing lists, H 109 is seen to be severely affected by some of the foreign cane diseases. To the diseases now present in these Islands it is fortunately resistant or but moderately susceptible. Eye spot is the greatest drawback to H 109, but, looking at the acreage as a whole, it is but a small proportion of the total acreage which is affected; the condition of most areas in which H 109 is grown is unfavorable for the development of eye spot, so that injury from this disease is restricted. H 109 is not readily infected with mosaic disease, under the conditions of these Islands, and when affected does not suffer as severely as Lahaina or the Tip canes. It is this degree of tolerance to the disease which has caused many planters to disregard mosaic, with the result that, in general, our

[1] Knowledge of the reaction of cane varieties to gumming disease is largely from conversations with D. S. North, of the Colonial Sugar Refining Company of Australia and Fiji. The knowledge of the reaction of cane varieties to streak disease is due to publications by H. H. Storey, Government Mycologist of the Union of South Africa. Knowledge concerning dry top rot of cane in Porto Rico is due to Julius Matz, pathologist of the Porto Rico Agricultural Experiment Station.

irrigated plantations with H 109 now have more general infection than the unirrigated plantations which grow more susceptible canes. It seems to be a conservative generalization to state that H 109 is rather resistant to most of the non-infectious diseases arising from soil characteristics.

TABLE II

The Susceptibility or Resistance of H 109 to the Diseases of these Islands

Name of disease	Causal agent	Distribution	Susceptibility to infection	Degree of injury after infection
Infectious				
Mosaic disease or yellow stripe	Not established as yet but presumably a filtrable virus	All Islands but not all plantations	Moderate	36% loss[1]
Eye spot	A fungus, *Helminthosporium sacchari*	On northern parts of Islands and gullies where light and air movement are lessened	Severe	0 to 38%[2]
Red stripe	A bacterial organism, *Phytomonas rubrilineans*	Kohala district only	Resistant	Negligible
Iliau	A fungus, *Gnomonia iliau*	Mauka fields in cold weather	Resistant	Slight
Ring spot	A fungus, *Leptosphaeria sacchari*	All plantations	Susceptible	Negligible
Pineapple disease of standing cane[3]	A fungus, *Thielaviopsis paradoxa*	Rare; occurs only once in several years and then in very small areas	Susceptible	Affected stalks a total loss
Non-infectious				
Hamakua type of Lahaina disease	Unknown	Not entirely determined; suspect—on windward soils		Resistant
Salt injury type of Lahaina disease	High salt content of soil solution	In semi-arid districts		Resistant
Pahala blight	Unknown	Kau district only		Moderate[4]
Sectional chlorosis	Unknown	All Islands		Negligible
Leaf freckle	Unknown	All Islands		Negligible
Limestone chlorosis	Unknown	Maui, Oahu, Kauai		Appreciable
Cane yellows type of chlorosis	Unknown	Maui, Oahu, Kauai		Appreciable

[1] From experiments by Kunkel in which mosaic seed was planted against healthy seed.
[2] Losses depend on situation; more than two-thirds of the H 109 acreage is entirely uninjured by eye spot.
[3] We have few instances where pineapple disease affects germination of seed pieces.
[4] Knowledge of the relationships of cane varieties to Pahala blight is chiefly due to J. C. Thompson, of the Hawaiian Agricultural Company.

In the following table, showing the reaction of Yellow Caledonia to some of the foreign diseases, only such diseases to which Yellow Caledonia has been exposed and observations made will be recorded:

TABLE III

The Susceptibility or Resistance of Yellow Caledonia to Infectious Foreign Cane Diseases

Name of disease	Causal agent	Susceptibility to infection	Degree of injury after infection
Fiji disease	Unknown	Severe	Severe
Gumming disease	*Phytomonas vasculara*	Resistant	Resistant
Leaf scald	A bacterial organism undescribed as yet	Resistant	Resistant
Sereh	Unknown	Susceptible	Less severely affected than Cheribon
Downy mildew	*Sclerospora sacchari*	Resistant	Resistant
Cane smut	*Ustilago sacchari*	Resistant	Resistant
Pokkah bong	Unknown	Unknown	Unknown
Curly top	Unknown	Susceptible	Severely affected
Dry top rot	*Plasmodiophora vascularum*	Susceptible	Unknown
Rust	*Puccinia kuehnii*	Resistant	Resistant
Yellow leaf spot	*Cercospora kopkei*	Slight	Resistant
Banded sclerotial leaf disease	Sterile fungus	Slight	Resistant

Except for Fiji disease, Yellow Caledonia is a cane fairly resistant to most of these infectious diseases. In these Islands it suffers less from infectious diseases than almost any variety. It is very susceptible to Pahala blight, but aside from this is comparatively resistant to the non-infectious diseases as well. Pahala blight, moreover, is restricted in extent to very small areas in the Kau district.

TABLE IV

The Susceptibility or Resistance of Yellow Caledonia to the Diseases of These Islands

Name of disease	Causal agent	Susceptibility to infection	Degree of injury after infection
Infectious			
Mosaic disease	Apparently a filtrable virus	Resistant	Severe
Eye spot	*Helminthosporium sacchari*	Resistant	Resistant
Red stripe	*Phytomonas rubrilineans*	Resistant	Resistant
Iliau	*Gnomonia iliau*	Susceptible	Moderate
Ring spot	*Leptosphaeria sacchari*	Susceptible	Negligible
Pineapple disease of standing cane	*Thielaviopsis paradoxa*	Resistant	Negligible
Non-infectious			
Hamakua-Lahaina disease	Unknown		Moderate
Salt injury type of Lahaina disease	High salt content of soil solution		Some degree of resistance
Pahala blight	Unknown		Severe
Sectional chlorosis	Unknown		Negligible
Leaf freckle	Unknown		Negligible
Limestone chlorosis	Unknown		Moderate
Cane yellows type of chlorosis	Unknown		Resistant

TABLE V

The Susceptibility or Resistance of D 1135 to Infectious Foreign Cane Diseases

Name of disease	Causal agent	Susceptibility to infection	Degree of injury after infection
Fiji disease	Unknown	Severe	Severe
Gumming disease	*Phytomonas vasculara*	Slight	Moderate
Leaf scald	A bacterial organism undescribed as yet	Resistant	Resistant
Downy mildew	*Sclerospora sacchari*	Resistant	Resistant
Rust	*Puccinia kuehnii*	Resistant	Resistant

The exposure of D 1135 to a number of the diseases of foreign countries has not been recorded or observed in as many instances as H 109 or Yellow Caledonia. Most of the observations of the reactions of D 1135 to these infectious agents have been made by D. S. North in Australia, where D 1135 has been grown to some extent for years, or in the Philippines where D 1135 has been recently introduced.

TABLE VI

The Susceptibility or Resistance of D 1135 to Diseases of These Islands

Name of disease	Causal agent	Susceptibility to infection	Degree of injury after infection
Infectious			
Mosaic disease	Apparently a filtrable virus	Resistant	31 to 41% according to Kunkel[1]
Eye spot	*Helminthosporium sacchari*	Resistant	Negligible
Red stripe	*Phytomonas rubrilineans*	Resistant	Negligible
Iliau	*Gnomonia iliau*	Resistant	Negligible
Ring spot	*Leptosphaeria sacchari*	Resistant	
Pineapple disease of standing cane	*Thielaviopsis paradoxa*	Resistant	Moderate
Non-infectious			
Hamakua Lahaina disease	Unknown		Moderate
Salt injury type of Lahaina disease	Excess salt content of soil solution		Moderate
Pahala blight	Unknown		Resistant
Sectional chlorosis	Unknown		Affected but injury negligible
Freckle	Unknown		Negligible
Limestone chlorosis	Unknown		Unknown
Cane yellows type of chlorosis	Unknown		Slight

A notable phenomenon is the resistance of D 1135 to infection with mosaic disease in these Islands, and its resistance to injury or tolerance of the disease once it is affected. In the West Indies, according to H. P. Agee, D 1135 is considered susceptible and sensitive following infection. To some extent, the same

[1] Cases of mosaic disease in D 1135 have been observed to recover and all symptoms of the disease disappear.

is true in the case of Yellow Caledonia; it is one of our most resistant canes in these Islands, while the early attacks of mosaic in Porto Rico were frequently most severe on Caledonia. There would seem to be an opportunity for valuable research as to the reasons for these differences in susceptibility.

Except for its susceptibility to Fiji disease, D 1135 seems to be resistant to most cane diseases, as well as most leaf diseases. It would seem to be very valuable as a parent for breeding resistant seedlings.

TABLE VII

The Susceptibility or Resistance of Lahaina to Infectious Foreign Cane Diseases

Name of disease	Causal agent	Susceptibility to infection	Degree of injury after infection
Fiji disease	Unknown	Severe	Severe
Gumming disease	*Phytomonas vascularа*	Severe	Severe
Leaf scald	A bacterial agent	Severe	Severe
Sereh	Unknown	Some degree of resistance	Moderate
Streak disease	Unknown	Susceptible	Unknown
Downy mildew	*Sclerospora sacchari*	Susceptible	Moderate
Cane smut	*Ustilago sacchari*	Slight	Slight
Dry top rot	*Plasmodiophora sacchari*	Susceptible	Unknown
Rust	*Puccinia kuehnii*	Resistant	Resistant
Yellow leaf spot	*Cercospora kopkei*	Slight	Slight
Banded sclerotial leaf disease	Sterile mycelium	Susceptible	Slight

Lahaina cane or, if we follow Noel Deerr as to synonyms, Otaheite, Bourbon or Louzier cane is very susceptible to a number of diseases as shown in the foregoing list. It is unquestionable that if Lahaina had not gone down with the various types of Lahaina disease, it would have been desirable to replace it because of its ready infection and severe injury from mosaic disease.

TABLE VIII

The Susceptibility or Resistance of Lahaina to Diseases of These Islands

Name of disease	Causal agent	Susceptibility to infection	Degree of injury after infection
Infectious			
Mosaic disease	Apparently a filtrable virus	Severe	Severe
Eye spot	*Helminthosporium sacchari*	Severe	Moderate
Red stripe	*Phytomonas rubrilineans*	Unknown	
Iliau	*Gnomonia iliau*	Moderate	Moderate
Ring spot	*Leptosphaeria sacchari*	Susceptible	Negligible
Pineapple disease of standing cane	*Thielaviopsis sacchari*	Susceptible	Severe

Non-infectious		
Hamakua Lahaina disease	Unknown	Severe
Salt injury type of Lahaina disease	Excess salt content of soil solution	Severe
Pahala blight	Unknown	Severe
Sectional chlorosis	Unknown	Unknown
Freckle	Unknown	Slight
Limestone chlorosis	Unknown	Severe
Cane yellows type of chlorosis	Unknown	Moderate

TABLE IX

The Susceptibility or Resistance of the Hawaiian-grown Type of Uba to Foreign Cane Diseases

Name of disease	Causal agent	Susceptibility to infection	Degree of injury after infection
Fiji disease	Unknown	Slight	Moderate
Gumming disease	*Phytomonas vasculara*	Resistant	Resistant
Leaf scald	A bacterial organism undescribed as yet	Resistant	Resistant
Streak disease	Unknown	Susceptible	Estimated 10% loss of cane tonnage
Downy mildew	*Sclerospora sacchari*	Severe	Severe
Cane smut	*Ustilago sacchari*	Severe	Severe
Rust	*Puccinia kuehnii*	Resistant	Resistant

It will be seen from the foregoing list that Uba, although highly resistant to one group of diseases such as gumming disease, leaf scald and Fiji disease, is extremely susceptible to cane smut and downy mildew. Since Uba is now being used extensively here as a parent in breeding new seedlings, it is highly important that such foreign diseases be excluded from these Islands.

TABLE X

The Susceptibility or Resistance of the Hawaiian-grown Type of Uba to the Diseases of These Islands

Name of disease	Causal agent	Susceptibility to infection	Degree of injury after infection
Infectious			
Mosaic disease	Apparently a filtrable virus	Immune	
Eye spot	*Helminthosporium sacchari*	Resistant	Negligible
Red stripe	*Phytomonas rubrilineans*	Resistant	Negligible
Ring spot	*Leptosphaeria sacchari*	Susceptible	Negligible
Pineapple disease of standing cane	*Thielaviopsis sacchari*	Resistant	Negligible

Non-infectious		
Hamakua Lahaina disease	Unknown	Resistant
Salt injury type of Lahaina disease	Excess salt content of soil solution	Resistant
Pahala blight	Unknown	Resistant
Sectional chlorosis	Unknown	Not observed
Freckle	Unknown	Slight
Limestone chlorosis	Unknown	Not observed
Cane yellows type of chlorosis	Unknown	Resistant

Uba cane is notably resistant to the various types of injuries which seem to arise from soil conditions. It would seem to be especially valuable as a parent in breeding towards resistance to such sort of injuries.

TABLE XI

The Susceptibility or Resistance of Badila to Foreign Cane Diseases

Name of disease	Causal agent	Susceptibility to infection	Degree of injury after infection
Fiji disease	Unknown	Some degree of resistance	More tolerant than most varieties
Gumming disease	*Phytomonas sacchari*	Resistant	Resistant
Leaf scald	A bacterial organism undescribed as yet	Resistant	Resistant
Streak disease	Unknown	Susceptible	Unknown
Cane smut	*Ustilago sacchari*	Resistant	Resistant
Downy mildew	*Sclerospora sacchari*	Resistant	Resistant
Curly top	Unknown	Resistant	Resistant
Rust	*Puccinia kuehnii*	Resistant	Resistant

From the foregoing list it can be seen that Badila is very resistant to a large number of infectious diseases; as a parent for breeding more productive seedlings, its desirability is self-evident.

TABLE XII

The Susceptibility or Resistance of Badila to the Diseases of These Islands

Name of the disease	Susceptibility to infection	Degree of injury after infection
Mosaic disease	Resistant	Severe
Eye spot	Resistant	Resistant
Red stripe	Resistant	Resistant
Ring spot	Moderate	Negligible
Pineapple disease of standing cane	Not observed	

Badila has not been observed under the conditions which develop many of the non-infectious diseases. It is known, however, to be resistant to Pahala blight.

The reaction to our diseases of some of the newly introduced Java canes may be of interest. P. O. J. 36, 213, 234 and 979 are all reputed to be readily susceptible to mosaic disease in the West Indies, but the statements are frequently made that the canes are tolerant of the disease and suffer very little loss following infection. There have been no figures available to us showing the degree of loss. Visual estimates of the degree of loss in the case of mosaic disease are of little value and it would be much more satisfactory to have the results from actual yields or at least from growth measurements in the case of these varieties.

These four Java varieties have been tested out in what we call our eye spot index tests. In these tests new varieties are tried out for eye spot susceptibility in comparison with H 109 and Yellow Caledonia. H 109 is given an empirical value of 1,000 to represent its susceptibility and Yellow Caledonia an empirical value of 0 to represent its resistance. In such tests P. O. J. 36 has an eye spot index close to 200; P. O. J. 213, 0; P. O. J. 234, almost 0; and 979 close to 100. It is safe to say that all four of these varieties are commercially resistant and can be grown in any district of these islands with no tangible losses from eye spot.

P. O. J. 36 and 234 have been reported to be affected by red-stripe disease.

Uba Hybrid No. 1 has an eye spot index of close to 500 and the losses from eye spot would be appreciable in districts favorable for eye spot infection such as Pahala, Naalehu, Waialua, etc.

W. W. G. Moir, of this committee, has some extensive observations on the eye spot susceptibility of the Hawaii 5,900 and 8,900 series, the Wailuku seedlings, the Manoa seedlings and Kohala seedlings. These observations are tabulated below in Table XIII:

TABLE XIII

Observations by W. W. G. Moir on the susceptibility or resistance to eye spot of the more promising seedlings of the H 5900 series, H 8900 series, the Wailuku series, Manoa series and Kohala seedlings.

Series	Highly Resistant	Slightly Susceptible	Readily Susceptible	Severely Affected
H 5900	H 5923	**H 5909**	H 5922	H 5908
	H 5978	H 5940		H 5972
	H 5965	H 5964		
		H 5974		
		H 5949		
H 8900	H 8907	H 8918	**H 8906**	H 8940
	H 8938	H 8929	H 8901	H 8947
	H 8945	H 8942	H 8911	H 8946
	H 8952	H 8948	H 8919	H 8949
	H 8961	H 8954	H 8920	H 8968
		H 8958	H 8922	H 8973
		H 8969	H 8928	H 8983
		H 8965	H 8924	H 8984
		H 8976	H 8933	H 8992

		H 8982	H 8935	
		H 8988	H 8956	
		H 8994	H 8978	
			H 89102	
Wailuku series	W 2	W 1	**W 4**	W 3
		W 5	W 6	
		W 9	W 7	
		W 11	W 8	
		W 51	W 10	
		W 63	W 12	
		W 73	W 13	
		W 71	W 17	
			W 48	
			W 50	
			W 53	
Manoa seedlings	**148**	**102**	**33**	
	160		**60**	
	185		**67**	
	186		**77**	
	187			
	188			
	209			
	213			
	198			
Kohala seedlings		K 107	K 73	
		K 115	K 117	
		K 202		

In the foregoing table the varieties in heavy type are those which seem to have considerable value for commercial plantings. In this list H 109 would be considered as belonging in the last column, that is, under "Severely Affected."

To review the plantation situation in regard to cane diseases in relation to varieties and the propagation of new seedlings:

The most immediate need seems to be for a cane equal to the Tip canes in production and in economy of production for mauka conditions on unirrigated lands which will also be resistant to mosaic disease, red stripe, and eye spot; the Tip canes which now occupy these lands are very susceptible to mosaic and red stripe.

The next need, possibly an equally important need, is a variety for those districts where the climatic conditions favor eye spot; a variety is needed equal to H 109 in production, equally resistant or more resistant than H 109 to mosaic disease and resistant to eye spot. This is a rather large order to fill, but is not impossible.

With such varieties and with the maintenance of the Islands free from new foreign diseases, these Islands would be ideally protected from losses from cane diseases.

Firing and Care of Locomotive Boilers*

By J. A. Good

The construction and upkeep of locomotive boilers have many features. One of the most essential is the correct application and care of tubes, and it is highly important that proper maintenance be given to securing the maximum results and minimum failures under operating conditions.

Tube troubles are the most general failures encountered in boilers and, where such exist, can very often be traced to mechanical causes, such as improper application or maintenance of tubes and to variation of temperature; yet many failures develop on account of inferior quality of tubes, which cannot at all times be detected on the surface or without an analysis or physical test.

The correct diagnosis of the causes is frequently the most important step in repair operations. Executives and employees who are responsible and interested in maintenance of locomotive boilers will find the study of these causes and the proper methods of making necessary repairs to be a very essential part of locomotive maintenance economy.

The firebox end is subjected to the most severe use and should be given the most careful attention so as to guard against hasty repairs which invariably give only a temporary relief and unnecessary delay and labor cost, and, sooner or later. result in taking the locomotive again out of service and doing the job right. In this regard, workmen should be instructed to take time to do work well from the first, as continual working on tubes has a very material effect in reducing not only the life of the tube ends but in some cases maltreating the tube sheet.

The use of roller or sectional expander on firebox end of tubes is largely a matter of local selection and the intelligence and skill of labor employed. Generally speaking, a roller expander should not be used by inexperienced men, who are very apt to over-roll excessively and reduce the tube gauge and in time injure the flue sheet. Preference in this case should be given to the ordinary type of sectional expander which is designed and most suitable to the tube size and sheet thickness. With the use of this type of expander, the chance of injury to tube or sheet is reduced to a minimum.

Leaky tubes also develop from vibration. This need not be considered of great importance as, under ordinary operating conditions, a properly set tube is well supported by the water surrounding it. The vibration encountered in the shipment of empty boilers can be the cause of loose tube ends; hence it is always advisable to lightly rework the tube ends of such boilers before placing them in service.

The abrasive action of cinders also causes "burnt off or cracked heads" and in turn develops leaky tubes. This is a condition well recognized by the railways throughout the world, using coal for fuel.

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Variation in temperature is a daily occurrence with all boiler tubes. Tubes can be heated and cooled very often without becoming loose, providing all connected parts are heated and cooled uniformly, but trouble and leaky tubes are bound to develop where the variation in temperature is unequal and every effort should be exercised to guard against this condition.

Definite instructions should be made to prohibit the shutting off of oil fire and running or coasting of engine without the burner on, as the cold air drawn through tubes will result in injuring the firebox and tubes. A coal fire partly out will also prove harmful when running. Careful firing, especially with coal, to guard against the sudden and excessive admission of cold air into the firebox will prevent leaks to a great extent and prove very beneficial to the operation of the locomotives. Where oil is used as fuel, the admission of cold air is much less due to firedoor being closed.

Firemen should at all times make it a point to close the firedoor after each shovelful of coal is applied, the result of which is bound to reflect on the life and condition of tube ends, and also the boiler.

Unequal variation in the water temperature caused by injection of feed water is also an important cause of leaks and the correct location of boiler check is of prime importance. Boiler check should be conveniently located, but as far as possible from the firebox.

When the boiler is being fed with water, the fire should be kept up. Should the throttle be closed at this time, it is advisable to use the blower to assist in circulating the water in the boiler.

Many consider that the most prolific cause of leaking tubes is incrustation. This will, of course, vary with the quality of water supplied to the locomotive and the district in which the locomotive is operating. Its remedy is careful attention and blowing off and washing out the boiler. The washing out should be done with water under a pressure of not less than 150 pounds with the use of cleaning rods, the result of which will do much to remedy this condition and in turn allow the locomotive to steam properly and with less fuel used.

In extreme cases proper treatment of feed water to reduce its propensity for scale formation is also advisable. The proper treatment in this respect should and can be best determined by first having the water analyzed to find out if water treatment is necessary. With this information, one is in a position to decide on the proper treatment.

As a general and remunerative procedure, the care of tubes and boilers by regular inspection for mechanical defects, by blowing off, by proper and effective boiler washing, and intelligent firing will prove of the greatest economy in locomotive operation and boiler efficiency. It might be well to suggest keeping an accurate record and definite time to have boilers washed. In any event boilers should be blown down and washed out as often as water conditions require.

While on the subject of boiler efficiency and economy, it is not amiss to call attention to the firing of an oil-burning locomotive. Oil firing differs very materially from that of coal, and more careful attention is necessary in oil-burning locomotives than in coal burning ones to render the combustion economical.

To produce the most satisfactory results, firemen should give their work close attention and both the fireman and engineer should work together. The fireman should change his fire as often as the engineer changes the throttle or reverse lever. This possibly will appear to some as being not always possible with labor conditions in the Territory. Nevertheless, a good fireman, by following out this method of firing an oil-burning locomotive, and by being watchful and diligent, can minimize the oil consumption to a noticeable degree. In fact a fireman on an oil-burning locomotive can save or waste more fuel than he can on a coal burner.

The first essential in good oil firing is the regulation of the oil feed directly in proportion with the requirements of the work. If followed out, this will result in the consumption of a minimum quantity of oil.

Increase in firing should immediately precede the opening of the throttle and a reduction should follow the closing of throttle. The engineer should give the fireman advance notice as both enginemen should work in harmony.

Forcing the fire on an oil-burning locomotive is liable to injure the firebox sheets and tubes and should therefore be avoided. In the event of an emergency making it necessary to force the fire beyond a reasonable point, care should be taken to provide sufficient water on crown sheet to prevent damage.

The burning of oil has a tendency to deposit a gummy substance on the firebox end of tubes. This is very likely to take place even with no appearance of smoke, soot, and even with careful firing.

The tubes of oil-burning locomotives should be cleaned of soot when running by placing a small quantity of sand in a funnel, the end of which has been inserted through opening in firedoor. This cleaning should be done while the locomotive is working hard. With long stroke of valves and throttle wide open, this will allow the strong exhaust to draw the sand through the tubes, cutting the soot and gum from them in its passage and discharging it from the stack. It is better to use the sand frequently and in small quantities than to use large amounts only a few times.

To secure the maximum boiler results, clean tubes, both inside and out, are a big factor, and the boiler should be continually inspected to see that none of the tubes are stopped up. Should there be any stoppage, the use of an auger of sufficient length to reach from end to end should be followed by a careful inspection.

In view of the ease with which the extravagant use of fuel can be effected in burning oil, it appears highly advisable to exert every effort to properly handle the locomotive, the burner, and accessories in order to obtain economical combustion and to guard against injury to boiler or firebox.

A Review of Our Present Fertilizer Practices Compared to Those of Ten Years or More Ago*

By J. A. Verret

We feel that considerable progress has been made in the use of fertilizer during the last ten years. The crop last year was slightly over 700,000 tons of sugar, the estimated crop this year is over 780,000 tons. These are the largest crops ever raised in the territory. These increases are not due so much to increased acreage as to increased yields per acre. The average yield will be over 6.5 tons of sugar per acre for 1925. The average sugar production for the last ten years was approximately 600,000 tons, about 5.00 tons of sugar per acre. The average acre yields for the years 1905-14, inclusive, were 4.87 tons sugar per acre.

The above figures show that during the last twenty years our acre yields have been gradually increasing.

These increased yields are due to a number of causes, such as, better mill recoveries, better varieties, especially H 109, as well as improvements in methods of cultivation. Good climatic conditions had a great deal to do with the splendid results obtained from the last two crops, but unless we are wide awake, we may not be able to take full advantage of good climatic conditions. We do not want it understood that we claim all these gains due to fertilization, but we do claim that a very appreciable part is due to a better understanding of the problems of fertilization.

Amounts of Fertilizer Used, Past and Present

In 1914, we used 44,000 tons of fertilizer. In 1924, the sugar plantations used 95,000 tons. In 1914, the area in cane to be fertilized (1915 and 1916 crops) amounted to 214,346 acres, thus showing a fertilizer application of 410 lbs. per acre per year, or about 800 lbs. per acre per crop. The area in 1924 (1925 and 1926 crops) was 229,244 acres, showing a present application of 825 lbs. per acre per year, or about 1550 lbs. per acre per crop. We thus see that the amounts of fertilizer used per acre have about doubled in the last ten years.

Present Quality of Our Fertilizers

Not only are we using much larger quantities of fertilizer than we did ten years ago, but we are also using more concentrated formulas. This is especially the case with nitrogen. The amounts of nitrogen used have more than doubled during the last ten years. This increase in the use of nitrogen was brought about as a result of field experiments by the Experiment Station, H. S. P. A.,

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on the various plantations, as well as by experiments and observations by the plantations themselves. The results of these tests almost always indicated large gains from the use of nitrogen. Such was not the case with phosphoric acid and potash. In a large number of cases, there is no response at all, and hardly ever is the response as great as from nitrogen.

This has led to a somewhat radical change in the formulas of our high grade fertilizers and to an increased use of soluble nitrogen fertilizers such as nitrate of soda and ammonium sulphate. We give below the average composition of the high grade fertilizers used from 1907 to 1915:

TABLE I

Average High Grade Formula

Year	Nitrogen	Phos. Acid	Potash
1907–08	6.33%	7.54%	10.53%
1908–09	6.21	7.78	10.33
1909–10	7.10	7.39	9.07
1910–11	8.21	7.13	8.19
1911–12	8.37	7.17	7.80
1912–13	8.61	6.77	7.89
1913–14	8.57	6.60	8.32
1914–15	8.63	6.76	7.33
8-year average	7.75	7.14	8.68

We give below some typical formulas used in the various districts at the present time:

No. 1.	12% N	5% Ammonium Sulphate 6% Nit. Potash 1% Organic
	5% P_2O_5	2% Superphosphate 3% Bone Meal
	10% K_2O	6% Nit. Potash 4% Sulph. or Muriate Potash
No. 2.	11% N	6% Nit. Potash 4% Ammonium Sulphate 1% Organic
	6% P_2O_5	3% Superphosphate 3% Bone Meal
	6% K_2O	Nit. Potash
No. 3.	9% N	2½% Nit. Potash or Soda 6% Ammonium Sulphate ½% Organic
	9% P_2O_5	4½% Superphosphate 4½% Bone Meal
	6% K_2O	Nitrate or Sulph.

Formulas of the type shown by No. 1 above are used in districts of potash shortage, such as the Hilo district.

Formulas of the type shown by No. 3 are for districts of phosphoric acid shortage. This is generally the upper elevations on all Islands. Instead of using a high phosphoric acid high grade, such as No. 3, often extra application of phosphates are made at planting time and to young ratoons. This generally consists of 500 to 1000 lbs. per acre of superphosphate, reverted phosphate or raw rock phosphate.

Formulas of the type of No. 2 are used when no great shortage of either phosphoric acid or potash is indicated.

Methods of Application

The tendency during recent years has been to apply the fertilizer in larger and fewer doses than was the case formerly. Sometimes as much as 1000 lbs. or more per acre of high grade are applied in one dose. Generally all the fertilizer for a two-year-crop is applied in three doses. Sometimes this is extended to four, and on some occasions, cut down to only two. Short ratoons get from 1 to 2 applications. Applying the fertilizer in fewer doses of course saves the extra cost of application; it also enables one to finish fertilizing at an earlier date, thus giving the cane an opportunity to mature before harvest, thereby giving better juices than would otherwise be the case.

Varying the number of applications (within reasonable limits, say, 3, 4 or 5 doses for long crops) in which a given amount of fertilizer is put on does not very materially affect the yield of cane.

Forms of Nitrogen Used

As the result of a large number of field tests conducted on the plantations, it has been found that under practically all conditions the best returns per unit of nitrogen both in cost and quantity are obtained from the more soluble inorganic salts, such as nitrate of soda or ammonium sulphate, rather than from organic sources such as dried blood.

Very little organic fertilizer is now used. Most of that which is used is in the form of bone meal in the mixed fertilizer, where it is used mostly to improve the mechanical quality of the mixture and not on account of superior quality as a fertilizer.

Of the inorganic salts of nitrogen, tests show no great variation between them. In the warmer districts the returns are practically equal between nitrate of soda, nitrate of lime and ammonium sulphate. In the cooler districts the nitrates are more rapid in action and the yields as a whole are somewhat better than from ammonium sulphate. It would therefore seem to be advisable to use nitrate of soda or lime on the mauka lands of the plantations, even at a somewhat higher price per unit of nitrogen, in preference to ammonium sulphate. The fast work of nitrate nitrogen may also be an advantage in the dry dis-

tricts where it is important to take full advantage of optimum moisture conditions. On the warm, well irrigated plantations, these differences are not so important.

Forms of Phosphoric Acid

Although the evidence is not as strong as in the case of nitrogen, the indications are very strong that in the majority of cases superphosphate will give better results than either reverted phosphate or raw rock phosphate, although in some instances raw rock has given unexpectedly good returns, particularly when costs are considered.

Soil Surveys

The work of the chemistry department of the Experiment Station, H. S. P. A., has been of great value in the last years in helping develop our present fertilizer practices. There has been considerable difference of opinion in the past as to the value of soil analyses. More especially was this true in regard to drawing conclusions from them as to fertilizer requirements. It is now felt that there has been built up a fund of sufficient information from the work on the soils of the sugar plantations to justify us in certain general conclusions as to the probable fertilizer response of the soils in various districts. This work was based upon the detailed study of the soils of field experiments carried on by the Agricultural department of the Experiment Station, H. S. P. A.

The work that was done on these various soils indicates that the amounts of the soil minerals soluble in 1 per cent citric acid solution are a valuable indication of the availability of the plant food in the soil.

The results tend to show that the soils which fail to give a response to phosphate fertilization are those which are not only high in citric acid soluble phosphates, but also have a good content of citric acid soluble, lime and silica. By a good supply of citric acid soluble phosphates we mean percentages of P_2O_5 greater than .004 per cent. This should be accompanied by approximately 0.15 per cent of soluble lime and silica. When these conditions occur, we feel very certain that there will be no response to phosphate fertilization.

The exact figures may be somewhat modified by later work, but we only consider that amounts notably less than these figures definitely indicate a phosphate shortage. In the samples from the phosphate experiments, there was a response to phosphate fertilization in practically every case where there was 0.0025 per cent or less of citric acid soluble phosphate, and a low content of soluble lime and silica.

Soils with a soluble phosphate content between these high and low figures vary in their response and require field tests to be certain. In such cases, as a matter of insurance to keep up soil fertility, the Experiment Station is inclined to recommend the use of some phosphate, unless financial conditions are such that strict economy is demanded for the time being.

The work with regard to potash would tend to show that a response is to be expected from soils with a citric acid soluble potash content below 0.025 per

cent when accompanied by low available lime. Soils with a citric acid soluble potash content above 0.03 per cent, with a fair amount of lime, generally do not respond to potash fertilization.

This work by the chemistry department has been of great value in enabling us to obtain very accurate ideas as to the fertilizer requirements of our various soils with very many less field tests than was formally the case. We also quote from Mr. Stewart as follows:

A low content of total potash or phosphates, accompanied by low, strong acid soluble, and low citric and soluble plant food, is much more certain to indicate a fertilizer response from potash or phosphates than is likely to be the case if the available plant food alone is low.

The percentage of acid soluble plant food is considered to be an indication of the degree of weathering and future solubility of the soil minerals. We ordinarily expect to find at least 0.2 per cent of hydrochloric acid soluble phosphates. The content of total phosphates should range from 0.35 to 1.00 per cent, depending upon the district in the Islands from which the sample was taken. The hydrochloric acid soluble potash is usually about 0.2 per cent or more. The total potash ranges from 0.3 per cent to 1.0 per cent. There is ordinarily about 0.25 per cent or more of hydrochloric acid soluble lime.

In these soil surveys the greatest variations were found on Kauai, especially on the plantations from Koloa to Kilauea. In this district the mauka fields are generally very poor, not only in phosphoric acid, but in potash and lime. On the other hand, some of the lower fields show up extremely well.

In the Hamakua district the physical aspects seem to play a larger part. The depth of soil, water-holding capacity, grade and exposure all exert a big part. On account of some or all of these characteristics, some fields are very poor, although the soil shows up well in plant foods.

The Effect of Nitrogen on the Quality of Cane Juices

The effect of nitrogen on cane juices is very important, so we present here some preliminary data bearing on the subject. Through lack of time, we were not able to finish the study we had undertaken. The data presented here extends to the year 1922 only. During next year we hope to finish up to date, always assuming that we have no labor troubles and that the plantations do not take away all the assistant agriculturists as they came very near doing this year.

The tables presented herewith are based on sixty-five nitrogen experiments and are intended to show the general effect on the juices as the amount of nitrogen used is increased.

Average Quality Ratios by Island

Pounds of Nitrogen per Acre

Location	51 to 100	100 to 150	151 to 200	201 to 250	251 and Over
Hawaii	7.66	7.72	7.86	8.02	8.12
Kauai	8.45	8.63	8.77	8.80	8.98
Maui	6.92	6.93	7.07	7.21	7.33
Oahu	8.09	8.34	8.40	8.49	8.77
Average ...	7.78	7.90	8.02	8.13	8.30

From the above table we find that, for amounts between 50 and 250 lbs. of nitrogen per acre, increasing the nitrogen 50 lbs. per acre, within these limits, increases the quality ratio slightly more than 0.1 ton of cane. That is, an increase of 50 lbs. of nitrogen requires about 0.12 ton of cane more to make a ton of sugar.

In order to express the above variations more clearly to some, the above table was worked out on a percentage basis using 151 to 200 lbs. of nitrogen per acre as normal.

PER CENT VARIATION IN QUALITY RATIO FOR VARYING AMOUNTS OF NITROGEN

Pounds of Nitrogen per Acre

Location	51 to 100	100 to 150	151 to 200	201 to 250	251 and Over
Hawaii	97.5%	98.3%	100.0%	102.1%	103.3%
Kauai	96.4	98.4	100.0	101.4	102.4
Maui	97.9	98.0	100.0	101.9	103.7
Oahu	96.4	99.3	100.0	101.0	104.4
Average ...	97.0	98.5	100.0	101.6	103.5

The above table may be used to calculate the quality ratios which we might expect were we to increase or decrease the nitrogen used, other factors remaining the same. Such a calculation was made, using the 1924 quality ratios for the Islands as given in the Annual Synopsis of Mill Data. It was assumed that we are now using from 151 to 200 lbs. of nitrogen per acre. The actual 1924 quality ratios are in the nitrogen column headed by these amounts. The figures in the other columns are the quality ratios which might be expected from the changed nitrogen.

POUNDS OF NITROGEN PER ACRE

Location	51 to 100	101 to 150	151 to 200	201 to 250	251 and Over
Hawaii	8.64	8.71	8.86	9.05	9.15
Kauai	7.83	7.99	8.12	8.23	8.31
Maui	7.42	7.43	7.58	7.66	7.86
Oahu	7.87	8.10	8.16	8.24	8.52
Average ...	8.00	8.13	8.25	8.38	8.54

SUMMARY OF THE RESULTS OF FIELD TESTS

LIME

For a number of years we have been conducting field experiments to determine the value of liming on the fields of the various sugar plantations. In this article we propose to give a summary of our results to date.

Some confusion exists in the popular mind with reference to the nature of lime and its use. Before proceeding with our summary, it may be well to discuss these points briefly.

When the chemist speaks of "lime" he refers to calcium oxide (quicklime) only, but when we refer to lime in the agricultural sense we include three different materials: burned or quicklime (calcium oxide), hydrated or water-slaked lime (calcium hydrate), and ground limestone or air-slaked lime (calcium carbonate). Gypsum, or calcium sulphate, is not included in the term "lime," although it contains calcium.

These materials contain various amounts of calcium as indicated. That is: 56 lbs. of quicklime equal 74 lbs. of hydrated or water-slaked lime or 100 lbs. of ground limestone. The other way about, 100 lbs. of quicklime equal 132 lbs. of water-slaked lime or 179 lbs. of ground limestone. With these figures in mind, one may figure the relative costs. When either quicklime or hydrated lime is exposed to the air, they gradually absorb carbon dioxide and tend to change to lime carbonate, or limestone.

The function of lime in soils is given briefly as follows:

1. Lime materials serve as a source of the element calcium to plants. Calcium is one of the essential elements in plant growth. As a rule most of our soils are pretty well supplied with calcium; besides this, we apply fairly large amounts of it in the phosphates which we use in our mixed fertilizer and directly.

2. Lime materials have the power of shrinking clay and making it more pervious to water and air. Lime, therefore, makes clays and adobe soils looser, and improves the mechanical condition of this type of soils.

3. Lime materials (when used in proper amounts) make "sour" soils "sweet", changing an acid condition into a neutral or slightly alkaline one. This is essential to many crops, but our tests indicate that sugar cane is very tolerant to sour conditions, although our best yields are obtained from neutral or slightly alkaline soils.

4. Lime materials are necessary for the beneficial bacteria and other microorganisms of the soil.

5. Lime materials promote the normal decay of organic matter in the soil.

6. Lime materials, under some conditions, make soluble some of the insoluble forms of the more valuable plant foods such as potash and the phosphates.

7. Lime materials, when added to nearly or complete neutrality, precipitate soluble alumina.

For the purpose of loosening heavy soils mentioned in (2) burned or hydrated lime is to be preferred when prices allow. It acts more quickly. Lime is best applied before plowing, several months before planting, particularly if quick or hydrated lime is used. On the sour, lighter, sandy or loam soils, ground limestone is to be preferred to either of the other two.

In the following table the results of our lime tests are given briefly and the results summarized:

Lime Experiments

	Plantation		Crop Year	Lime Cane	Lime Sugar	No Lime Cane	No Lime Sugar
1.	Waipio Substation 0		1916	80.4	11.15	80.1	10.85
2.	" " 0	(Residual)	1918	88.0	9.87	84.1	9.29
3.	" " 0	(Residual)	1920	66.1	8.37	64.2	8.34
4.	Wailuku Sugar Co............ 1		1917	86.4	12.40	81.2	12.18
5.	" " " 1	(Residual)	1919	74.1	10.87	71.2	10.68
6.	Kilauea Sugar Plan. Co........ 4		1917	27.2	3.09	25.5	2.94
7.	" " " " 7		1918	31.9	3.73	31.5	3.69
8.	Oahu Sugar Co................ 8		1918	67.8	7.25	65.6	7.18
9.	Hilo Sugar Co.................18		1921	47.3	5.91	45.2	5.65
10.	" " " 18	(Residual)	1923	58 9	6.65	56.8	6.31
11.	Hawi Mill & Plant. Co........ 2		1919	54.0	6.86	52.3	6.59
12.	Paauhau Sugar Plan. Co.......10		1919	46.7	5.62	45.6	5.57
13.	Niulii Mill & Plan. Co......... 1		1922	16.7	1.92	15.2	5.97
14.	Kaiwiki Sugar Co............ 1		1917	42.1	5.65	40.9	5.67
15.	Hamakua Mill Co............. 1		1918	15.3	1.93	15.2	1.96
16.	" " " 1	(Residual)	1920	26.7	3.53	26.5	3.52
17.	" " " 2		1918	11.2	1.34	11.0	1.34
18.	" " " 2	(Residual	1920	20.8	2.63	19.6	2.43
19.	Oahu Sugar Co................17		1918	67.3	6.03	67.6	6.11
20.	" " " 17	(Residual)	1920	96.6	13.70	101.6	13.68
21.	Grove Farm Co., Ltd........... 8		1920	40.7	4.83	41.9	4.98
22.	" " " " 8	(Residual)	1922	34 8	4.16	35.5	4.18
23.	Kaiwiki Sugar Co............ 4		1922	24.5	3.21	24.6	3.39
24.	" " " 4	(Residual)	1924	36.2	4.60	34.6	4.33
25.	Pepeekeo Sugar Co............ 5		1922	49.7	6.45	51.7	6.52
	Average			48.5	6.07	47.6	5.97
	Average Quality Ratio.....		Lime....7.99			No Lime....7.97	

Since 1916, we have conducted a total of twenty-five lime experiments. These were on all the Islands and covered our various soil types.

In looking over the summary we find that in thirteen of the twenty-five some gains were obtained; in twelve there were no gains from the lime. In practically no case were the gains especially large or significant.

The cane plant would seem to tolerate very wide fluctuations in the lime reaction of a soil. We find very good crops being produced on lands which are almost pure coral; good crops are also produced on soils which are extremely acid, requiring 10 to 12 tons of lime to bring to neutrality. This shows that with us the lime problem is not an especially vital one.

The conditions under which liming would be most likely to give the best returns are on the acid mauka soils which respond to phosphoric acid. Liming such soils would improve conditions for the phosphates and likely tend to an economy in their use.

The average quality ratio of the juices from lime plots was 7.99, while that from the no lime plots was 7.97. We thus see that lime had no effect whatever on the quality of the juices.

The Effects of Phosphoric Acid and Potash on Cane Juices

During recent years the average quality of cane juices on the different islands has shown a downward tendency. The question has been raised as to whether our systems of fertilizing were in any way responsible for this. With this in mind we have recently made a rather careful review of all our fertilizer experiments and compared the juices from the plots receiving different fertilizer treatments. In this paper we are reporting the results of this study in regard to the effect of phosphoric acid and potash.

The Action of Phosphorus and Potassium on Plants

Before going into the details of the results of our experiments here, we shall give briefly the effects produced on crops by these two elements as given in the literature. These general conclusions given by the different authors are based almost entirely upon temperate zone plants, mainly cereals.

Phosphoric acid is very beneficial in favoring the rapid development of young plants by stimulating the growth of roots. This points to the importance of the early application of phosphates.

Protoplasm cannot exist without phosphorus, and as there can be no plant growth without protoplasm this is very important.

Phosphates are reported to favor the early ripening of crops. The formation of grain is hastened by the free application of phosphates. This maturing effect of the phosphates is due to this hastening of seed formation. Phosphorus is always found more abundantly in the seed than in other parts of the plant. In non-seed crops this maturing effect may not be evident.

Potassium compounds are necessary in order that a plant may produce starch, sugar, cellulose and other carbohydrates. Potassium seems to be necessary for transference of starch from the leaves to other parts of the plant. Potash plays a large part in the development of leaves and the woody parts of the stems of plants. Larger portions of potash are found in these parts of plants. Large amounts of potash tend to prolong the life of plants, thereby delaying maturity, and thus having an effect directly opposite to that of phosphoric acid. Here we have an indication of the importance of early application of potash compounds in order that the potash needed may be used as early as possible and give time for the plant to mature. Potassium compounds give the plant more resistance to the attacks of fungous diseases, such as rusts, especially. Crops not receiving enough potash seem to be more susceptible to diseases of all kinds.

Experimental Results

The results herein reported are based on a total of 118 experiments, covering all the Islands and extending from 1917 to 1925.

Each experiment consisted of from 5 to 12 repetitions of each treatment. In nearly all cases, all plots were sampled, and ~~the juices~~ averaged for each treatment. The figures given are the averages of several hundred juice analyses, com-

posed of over a thousand samples, and it would therefore seem that the results obtained can be accepted as more or less conclusive.

The results show no effect whatever on the quality ratio of juices from the use or omission of either phosphoric acid or potash or both. This statement has no reference to the effect of phosphoric acid on the clarifying properties of a cane juice. Recent work by Walker, of Pioneer Mill Company, and McAllep, of this Station, points to the fact that the phosphoric acid content of a cane juice has a very important bearing in factory work. When below a certain minimum of phosphoric acid, juices clarify rather poorly. What that minimum is, or what its relation is to the phosphoric acid content of the soil, is not yet clearly established, as some obscure points remain to be worked out. For instance, the juice from certain fields may be rather low in P_2O_5 and not clarify very well, yet the cane fails to respond to phosphate applications.

Below we give in tabular form a summary of the results obtained from the different treatments:

Phosphoric Acid

	Quality Ratio of Juice	
	Phos. Acid	No Phos. Acid
Average of all experiments responding to phosphates........	8.31	8.29
Average of all experiments not responding to phosphates....	8.55	8.49
Average of all..	8.44	8.39

Potash

	Quality of Juices	
	Potash	No Potash
Average of all experiments responding to potash applications........	8.27	8.26
Average of all experiments not responding to potash applications....	8.24	8.17
Average of all..	8.25	8.22

Phosphoric Acid and Potash

	Quality of Juices	
	Phos. Acid and Potash	No Phos. Acid and Potash
Average of all experiments responding to phosphoric acid and potash..................................	8.24	8.18
Average of all experiments not responding to phosphoric acid and potash..................................	7.36	7.30
Average of all..	7.92	7.86

The above results show that in arriving at the cause of our poorer juices we must look elsewhere than to the presence or absence of phosphoric acid or of potash in our fertilizers. We have previously shown what effect nitrogen has.

Some of these causes may be adverse climatic conditions, change of cane varieties, late harvesting, late fertilizing, increased nitrogen applications, increased yield of cane per acre, or age of cane when harvested.

Some of the above factors we can control, others we cannot. When Lahaina refuses to grow we must change to another variety of cane, even though the juices be poorer. We cannot do much with climate, but we can fertilize earlier.

With our present labor conditions, late harvesting is to be expected. Beginning in July, cane juices go back very fast. But this "going back" seems to is, cane 24 to 30 months old seems to deteriorate much more than is the case with apply to old cane to a much greater degree than it does to younger cane—that cane 15 to 18 months old. Our best juices last year at Waipio were from short ratoons harvested in late August. We do not believe that these short ratoons had deteriorated at all when harvested.

We feel that this question of short ratooning is a very important field for more extensive experimentations on the plantations.

We would suggest the trial of short ratooning to the extent that all cane ground from July on be short ratoons.

There is a possibility that the sugar made from this younger cane late in the year would have a better refining value than sugar made from older, deteriorated cane. Deterioration of cane is accompanied by more or less gum formation, and this, in turn, has a direct bearing on the filtering quality of the sugar.

Quality of Juices in Potash Experiments

Experiments	Quality Ratio of Juice Potash	No Potash	Gain from Potash
HAWAII			
Hakalau 13, 1923, Field H8	8.64	8.22	Yes
Hakalau 13, 1925	8.66	8.57	Yes
Hamakua 5, 1922	7.74	7.30	No
Honokaa Obs. B, 1921	7.40	7.65	Yes
Onomea 6, 1918	8.42	8.27	Yes
Onomea 6, 1920	8.64	8.58	Yes
Onomea 6, 1922	7.95	7.77	Yes
Onomea 8, 1919	7.61	8.11	Yes
Onomea 8, 1921	7.67	8.56	Yes
Onomea 8, 1923, Field 25	8.20	8.49	Yes
Onomea 9, 1919	7.62	7.91	Yes
Onomea 9, 1921	7.32	7.27	Yes
Onomea 11, 1922	7.71	7.25	Yes
Pepeekeo 6, 1922	8.05	7.88	Yes
KAUAI			
Kilauea 23, 1920	9.58	9.94	Yes
Kilauea 24, 1920	9.73	9.73	Slight
Kilauea 25, 1921	8.30	8.29	Slight
Kilauea 31, 1922	9 58	9.55	No
Kilauea 31, 1924, Field 37	8.96	8.85	Slight
Koloa 5, Field 5	9.04	8.83	Yes
Lihue 2, 1921	8.81	8.78	No
Lihue 7, 1922	7.65	7.76	No
Makee Sugar 3, Field 13	8.27	8.30	Yes
McBryde 2, 1919	7.53	7.43	No
McBryde 2, 1921	7.24	7.41	No

MAUI			
H. C. & S. Co 7, 1921	6.78	6.80	No
M. A. Co. 8, 1921	8.85	8.90	No
Pioneer 4, 1921	6.70	6.73	Slight
OAHU			
Oahu Sugar Co. 4, 1920	7.41	7.46	No
Oahu Sugar Co. 8, 1922	8.60	8.64	No
Oahu Sugar Co. 14, 1920	7.13	6.89	No
Waipio V, 1917	9.00	9.11	No
Waipio V, 1918	9.37	9.12	No
Waipio V, 1919	8.68	8.29	No
Waipio V, 1921	9.13	9.13	No
AVERAGE			
Average of all experiments	8.25	8.22	
Responding to potash	8.27	8.26	
Not responding to potash	8.24	8.17	

Quality of Juices in Phosphoric Acid Experiments

Experiments	Quality Ratio of Juices Phosphoric Acid	No Phosphoric Acid	Gain from Phos. Acid
HAWAII			
Hakalau 4, 1919	8.12	8.19	No
Hakalau 7, 1919	7.58	7.67	No
H. M. Co. 3, 1922	7.24	7.27	Yes
H. M. Co. 5, 1922	7.58	7.47	No
H. A. Co. 2, 1922	8 26	8.29	Yes
Honomu 1, 1919	8.73	8.57	No
Onomea 9, 1919	7.55	7.81	No
Onomea 9, 1921	7.40	7.19	No
Paauhau 12, 1919	8.02	8.01	Slight
Paauhau 12, 1921	9.43	9.48	Yes
Paauhau 17, 1923	10.65	10.37	No
Pepeekeo 1, 1917	7.08	7.02	No
KAUAI			
Grove Farm 6, 1919	8.11	7.95	No
Grove Farm 9, 1922	7.92	8.33	Yes
Kilauea 5, 1917	9.50	9.38	No
Kilauea 7, 1918	8.58	8.54	No
Kilauea 17, 1920	9.71	9.62	No
Kilauea 17, 1922	11.40	11.12	No
Kilauea 27, 1921	9.40	9.20	Yes
Kilauea 29, 1922	8.26	8.29	Yes
Kilauea 30, 1922	8.19	7.76	Yes
Kilauea 30, 1924, Field 37	8.44	8.24	Yes
Kilauea 34, 1921	8.68	9.04	Yes
Kilauea 35, 1921	8.87	8.92	Yes
Lihue 1, 1921	8.91	8.71	No
Lihue 2, 1921	8.80	8.92	No

Lihue 6, 1922	8.40	8.00	Yes
Lihue 7, 1922	7.70	7.80	Yes
McBryde 2, 1919	7.48	7.42	No
McBryde 2, 1921	7.51	7.23	No
MAUI			
H. C. & S. Co. 7, 1921	6.76	6.79	Yes
M. A. Co. 8, 1921	8.99	8.71	No
Pioneer 3, 1921	7.27	7.18	No
Pioneer 4, 1921	6.71	6.71	Slight
OAHU			
Oahu Sugar Co. 4, 1922	8 95	8.72	Yes
Oahu Sugar Co. 6, 1918	9.50	9.53	Yes
Oahu Sugar Co. 6, 1920	7.02	7.02	Yes
Oahu Sugar Co. 6, 1922	8.24	8.66	Yes
Oahu Sugar Co. 14, 1920	7.11	7.11	Yes
Waipio V, 1917	8.94	8.89	No
Waipio V, 1918	9.29	9.46	No
Waipio V, 1919	8 53	8.54	No
Waipio V, 1921	9.15	9.15	No
Averages	8.44	8.39	
Averages of experiments which responded to Phosphoric Acid	8.31	8.29	
Averages of experiments which did not respond to Phosphoric Acid	8.55	8.49	

Quality of Juices in Plant Food Experiments

Experiments	Quality Ratio of Juice Nitrogen Phos. Acid and Potash	Nitrogen Only	Gain from Phos. Acid and/or Potash
HAWAII			
Hamakua 5, 1922	7.78	7.23	No
Halawa 3, 1924	7.46	7.58	Slight
Honokaa 10B, 1924, Field 19	8.69	8.01	No
Niulii M. and P. 2, 1924, Field 8	7.87	7.89	Slight
Onomea 9, 1919	7.77	8.14	Yes
Onomea 9, 1921	7.34	7.08	Yes
Union Mill Co. 2, 1924, Field 94	7.65	7.66	Slight
KAUAI			
Koloa 9, 1924, Field 20	9.67	10.16	Yes
Koloa 11, 1924, Field [illegible]	7.12	7.65	Slight
Koloa 14, 1925, Field 51	8.92	8.65	Slight
Lihue 2, 1921	8.92	8.78	No
Lihue 2, 1923, Field 1	8.61	8.49	Yes
Lihue 7, 1924, Field 13	8.68	8.24	No
Lihue 7, 1922	7.80	7.80	No
McBryde 2, 1919	7.53	7.42	No

MAUI			
H. C. & S. Co. 7, 1921	6.76	6.80	No
M. A. Co. 8, 1921	8.71	8.98	No
Pioneer 4, 1921	6.71	6.73	Yes
Pioneer 4, 1923, Field 1	8.61	8.49	Yes
Pioneer 4, 1925, Field B6L	6.90	6.80	Yes
Pioneer 7, 1924, Field B2	7.53	7.53	Yes
Pioneer 8, 1924, Field 31	7.00	6.79	Slight
Pioneer 11, 1924, Field 4	8.66	8.65	No
Pioneer 13, 1925, Field B-4	6.40	6.20	Slight
Pioneer 17, 1925, Field 32	7.37	7.41	No
Pioneer 20, 1925, Field L. A. 7	7.50	6.96	No
Pioneer 22, 1925, Field G-2	6.40	6.40	Yes
Pioneer 26, 1925, Field C-8	8.38	8.50	Slight
Wailuku 11, 1923, Field 37	8.18	8.04	Slight
Wailuku 12, 1923, Field 17	7.44	7.31	Slight
Wailuku 13, 1923, Field 70	8.46	8.51	Slight
Wailuku 14, 1923, Field 19	7.93	7.94	No
Wailuku 15, 1923, Field 100	8.38	8.45	Yes
OAHU			
Oahu Sugar 4, 1920	7.88	7.56	Yes
Oahu Sugar 14, 1920	7.11	7.00	Yes
Waipio V, 1917	9.59	9.53	No
Waipio V, 1918	9.41	9.54	No
Waipio V, 1919	8.06	7.90	No
Waipio V, 1921	9.15	9.15	No
Waipio V, 1923, Sec. 36	8.36	8.44	Slight
Waipio LI, 1925	8.44	8.44	No
Averages	7.98	7.92	
Average of experiments which responded	7.76	7.75	
Average of experiments which did not respond	8.29	8.16	

Hawaiian Factory Data*

By G. H. W. Barnhart

One interesting phase of a comparison of data covering the different factories in Hawaii is the great variety in size and arrangement of equipment, which, to all intents and purposes, is thoroughly standardized. There are nine distinct lengths of mill rollers ranging from 42 inches, at Waimea, to 84 inches, at McBryde, these mills being not more than six miles from each other. Hawaii has one two-roller crusher and six-roller mill at Halawa. There are seventeen nine-roller mills, eleven preceded by two-roller crushers, four by three-roller crushers and two by no crusher at all. Of twenty twelve-roller mills (two factories having two tandems each), seventeen are preceded by two-roller crushers,

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one by a three-roller crusher and two by no crusher at all. There are two fifteen-roller tandems, each preceded by a two-roller crusher, and two eighteen-roller tandems, one preceded by a two-roller, the other by a three-roller crusher. The predominance of the twelve-roller tandem, with two-roller crusher, indicates it as standard equipment. Thirty-six of forty factories use crushers, seven of these being three-roller crushers, which are popular because the installation is identical with a three-roller mill except for the coarser grooving and because of a somewhat better extraction. Twenty-nine factories report the use of knives, eight of them having double sets. There are fourteen Searby Shredder installations, while one old National is still doing service.

Practically every size of engine offered by manufacturers is to be found, the predominating makes being the Putnam, Edward Wood, Hamilton Corliss and Nordberg. The possible indicated horse power (I. H. P.) developed in each factory has been found by calculation, using the size, speed and initial and final pressures reported and a mean effective pressure (M. E. P.) corresponding to .40 cut-off. It will be noted that this I. H. P. capacity per T. C. H. varies from 10.1 at Halawa to 39.8 at Olowalu. Observations indicate that for a fairly uniformly loaded mill train the power required varies as the number of mills in the train—being 30 I. H. P. per T. F. H. for three-roller crushers and three-roller mills and 15 I. H. P. for two-roller crushers. Assuming an average fibre of 12½ per cent these figures become 3.75 and 1.875 I. H. P. respectively per T. C. H. and the power requirements for different mill arrangements are:

Arrangement	I. H. P.	Arrangement	I. H. P.
6 RM and 2 RC	9.875	12 RM and 2 RC	16.875
9 RM	11.250	12 RM and 3 RC	18.750
9 RM and 2 RC	12.625	15 RM and 2 RC	20.625
9 RM and 3 RC	15.000	18 RM and 2 RC	24.375
12 RM	15.000	18 RM and 3 RC	26.250

A comparison of the available with that required indicates five factories to be underpowered. A few have sufficient power and many have quite an excess, notably Honomu, with 245 per cent, and Olowalu, with 265 per cent, of requirements. In these calculations 0.40 cut-off was taken arbitrarily as this is about the limit for the Corliss valve. The results therefore indicate the normal maximum power available. That many installations are overpowered is of an advantage, as this permits cut-off nearer the point which will insure a minimum steam consumption.

To assist in determining the average capacity of a cane mill for Hawaiian conditions the table below is given. All mills in this class are preceded by revolving knives and a crusher:

Size of mill and Number of rollers		Tons fibre hour	Tons cane per hour at fibre of 10%	11%	12%	13%	14%	15%
26 x 42	9 RM	1.82	18.2	16.6	15.2	14.0	13.0	12.1
26 x 42	12	2.24	22.4	20.4	18.7	17.2	16.0	14.9
26 x 54	9	2.52	25.2	22.9	21.0	19.4	18.0	16.8
26 x 54	12	2.94	29.4	26.7	24.5	22.6	21.0	19.6
30 x 60	9	3.78	37.8	34.4	31.5	29.1	27.0	25.1
30 x 60	12	4.33	43.3	39.4	36.1	33.3	31.0	28.9
32 x 60	9	4.06	40.6	36.9	33.8	31.2	29.0	27.1
32 x 60	12	4.76	47.6	43.3	39.6	36.7	34.0	31.7
32 x 60	15	5.32	53.2	48.4	44.2	40.9	38.0	35.5
32 x 66	9	4.76	47.6	43.3	39.6	36.7	34.0	31.7
32 x 66	12	5.32	53.2	48.4	44.2	40.9	38.0	35.5
32 x 66	15	6.02	60.2	54.7	50.1	46.4	43.0	40.1
34 x 72	9	5.88	58.8	53.5	49.0	45.3	42.0	39.2
34 x 72	12	6.58	65.8	59.8	54.7	50.6	47.0	43.8
34 x 72	15	7.28	72.8	66.2	60.6	56.0	52.0	48.5
34 x 78	9	6.30	63.0	57.3	52.5	48.5	45.0	42.0
34 x 78	12	7.14	71.4	64.9	59.4	54.9	51.0	47.6
34 x 78	15	8.13	81.3	73.9	67.7	62.5	58.0	54.2

The maximum possible capacity is considerably in excess of the figures given, but these represent the grinding rate at which uniformly good work can be maintained.

The installation of a Searby Shredder in any of these installations, after the crusher, can be expected to increase the capacity as much as 20 per cent without affecting the extraction, or to increase the extraction 2.5, 1.25 or 0.8 per cent respectively, depending on whether the installation consists of a 9-, 12- or 15-roller mill, if the grinding rate is not increased. Records are available which indicate grinding rates 50 per cent in excess of the above figures as a direct result of the shredder installation.

Boilers

Boiler heating surface has been calculated on a basis of fire tube boilers, water tube surface being included as fire tube surface by multiplying it by 1.2. Excluding Honolulu Plantation, which refines its sugar and requires a greater heating surface, the range is from 275 square feet, at Niulii, to 676 square feet at Kohala, the average being 470, which is slightly more than the Hawaiian standard of 450 square feet in fire tube boilers.

Grate area ranges from one square foot per 52.7 square feet of boiler heating surface, to one per 200.0. Excluding the two low and three high figures the range is from 75 to 145 and the average 97.5 is roughly one square foot of grate area per hundred square feet of boiler heating surface.

Combustion volume, as measured to the point where gases first come in contact with boiler tubes or shell, ranges from one cubic foot per 3.125 square feet of boiler surface to one per 14.93. Omitting the four extremely low and five extremely high figures, the range is 5.15 to 9.61 and the average 7.45, so

that one cubic foot of volume to each 7.50 square feet of heating surface may be taken as an average.

Grate area ranges from 1.93 to 7.33 square feet per T. C. H. and combustion volume from 7.10 to 127.2 cubic feet per T. C. H., both of which indicate the extreme variation through which it is possible to obtain passable or even good work.

Juice Heaters

Tubular juice heaters are used exclusively to heat juices in these Islands, and the baffled type is being rapidly adopted. Heaters are used either for heating or reheating raw juice, or reheating the secondary mixed juice in the case of the Petree process and use live or exhaust steam or vapor from a pre-evaporator as the heating medium.

The various capacities per T. C. H. reported range from 18 to 54.5, the average being 28.8 for mixed juice, as compared with the Hawaiian standard requirement of 35 square feet, and from 9.00 to 22.67 for reheating. In the juice heater, work done is dependent on heating surface and steam pressure, a restricted surface requiring a high steam pressure, a low pressure necessitating a large heating surface. The heating surface required may be calculated from the formula $H.S. = \dfrac{10.23 \times T_d \times J}{T_m \times K}$ where

T_d = temperature rise in F°.
J = tons of juice per ton of cane (1.2 for mixed juice—1.3 for clarified)
T_m = mean temperature difference between juice and steam.
K = decimal figure expressing efficiency of steam with steam at zero gauge as unity. (For each 1 lb. increase or decrease in pressure, increase or decrease the figure 4.4 per cent.)

The calculation indicates 16.7 square feet at 8 pounds gauge, 22.3 at 5 pounds and 33.1 at 2 pounds gauge.

Settling Tanks

Seven of forty factories report the use of continuous settlers, four using Dorrs, and two the Colonial Sugar Refining type. Of the remaining factories, twenty use cylindrical tanks with conical bottoms, one uses old boilers, three use rectangular tanks with sloping bottoms and five simply designate their tanks as of the intermittent type. Capacities range from 51 to 121.8, the average being 81.2 cubic feet per T. C. H., as compared with the standard requirement of 72 cubic feet.

Filter Presses

The filtering area ranges from 58.8 to 160.0 square feet per T. C. H., the average being 103.7 where standard practice requires 120 square feet. Excluding the high and low figures 73 per cent of the factories have areas ranging between 91.5 and 134.5 square feet. Filter presses are not used in three Petree process

factories. Kopke centrifugal separators, however, have been installed in one factory to assist in reducing the quantity of impurity in circulation. The centrifugal area now used—0.44 square feet per T. C. H.—is insufficient. An area of one square foot per T. C. H. is recommended in conjunction with Peck strainers using 150-mesh wire cloth.

Pre-Evaporators

Nineteen factories report this equipment. One has discontinued its use, another uses it as a pre-evaporator "ordinarily" and as the first effect of a quadruple when the mill engines stop; a third uses vapor for heaters and pans, a fourth sends vapors to heaters and the final body of a triple, and one uses vapors for heating, reheating and in a double effect. The remainder is used with triple or quadruple effects.

The pre-evaporator may be installed either as a means of increasing evaporation capacity, or for fuel conservation, or both. It is difficult to state just where a pre-evaporator becomes necessary from a capacity standpoint. Since the capacity of a quadruple effect can be increased 66 per cent by raising the initial pressure from 2 to 8 pounds, and an additional 26 per cent if syrup is sent on at 60 instead of 70 Brix, it is apparent that practically double the amount of work can be done at this station provided those in charge are willing to sacrifice at other stations. Ample pan capacity will warrant passing on the syrup at 60 Brix, and large mill engines will enable the mill to operate against a high back-pressure with a higher steam consumption. Where live steam is used in processing in fairly large quantities and extra fuel is required, the pre-evaporator will ordinarily prove a desirable addition.

Reported pre-evaporator capacities range from 32 to 112.3 square feet of heating surface per T. C. H. The following tabulation indicates the surfaces required when the pre-evaporator is used for heating the entering juices and doing some evaporating, the vapors being used for heating the mixed juice to 212° F., the calandria pressure being as shown:

	Steam pressure—pounds gauge				
	6	7	8	9	10
Square feet H. S. for heating	14	9	6	4	3
Square feet H. S. for evaporation	115	64	45	36	30
Total H. S. required	129	73	51	40	33

Evaporators

Ten factories report the use of triple effects, seven of these being in conjunction with pre-evaporators. In the tabulation the surface of triple effects has been expressed as quadruple heating surface by multiplying by 4/3. Heating surfaces range from 160 to 394 square feet per T. C. H. Two hundred twenty-five square feet has been taken arbitrarily as the dividing line between insufficient and sufficient or ample capacity. Six of the factories with surfaces from

211.5 to 223 are just below. Three of these five use pre-evaporators. Three other factories with 160, 181 and 185.3 square feet respectively, appear to be decidedly deficient. The two last are supplemented with ample pre-evaporator capacity which is equivalent to 40-45 square feet in a quadruple. The first with 160 square feet and without an assisting pre-evaporator is apparently hard put to thicken its juices. An excess of heater capacity, however, assists by heating entering juices to the boiling point in the first cell of the evaporator, and a rather unusually large pan capacity enables handling the thin syrup sent to this station, although this is at a sacrifice in steam economy. Three factories report the use of Lillie evaporators in conjunction with standard effects. One uses a horizontal submerged tube evaporator.

The heating surface required in an evaporator is dependent primarily on the steam pressure in the calandria of the first cell, although the density to which evaporation is carried, and the vacuum in the last body each has its effect.

That required under varying conditions is given below:

Initial pressure pounds gauge	26" vacuum in last body 13–70 Brix	26" vacuum in last body 13–60 Brix	24" vacuum in last body 13–70 Brix	24" vacuum in last body 13–60 Brix
2	350	303	431	376
5	255	228	302	271
8	201	182	232	212

The Extra Use of Steam

In view of the diversity in the arrangement and amount of heating surface used in evaporation to syrup, some comment is in order. Since standard arrangement appears to include the quadruple effect the steam requirement with this equipment has been contrasted in the table below with other arrangements:

	Tons steam per ton cane hour	Per cent
Exhaust steam to		
Triple, heaters and pans	0.5924	117.7
Triple, pre-evaporators and pans (vapors to heaters)	0.5432	107.8
Quadruple, heaters and pans	0.5041	100.0
Quadruple, pre-evaporators and pans	0.4734	94.0
Quintuple, heaters and pans	0.4712	93.5
Quintuple, pre-evaporators and pans	0.4217	83.7

The economy of a quadruple over a triple and pre-evaporator, and of the latter over a straight triple, is apparent. Twelve Hawaiian factories have a pre-evaporator in addition to a quadruple. The tabulation shows a very slight difference in economy in favor of a quintuple over a quadruple and pre-evaporator. The controlling factor undoubtedly is the capacity, for with the same total heating surface, the combination with a pre-evaporator has 15 per cent greater capacity.

Pan Supply Tanks

Excluding the few extremely low and high valves, the total supply tank capacities range from 60 to 134 and the average is 90.5 cubic feet per T. C. H. for combined syrup, remelt and molasses. In general, this capacity is divided about equally between syrup with remelt, and molasses.

Vacuum Pans

The following pan capacities are desirable when cane polarizes 14, and syrup purity varies as given below:

	Syrup gravity purity						
	90	88	86	84	82	80	78
Shipping sugar	42.1	41.4	40.8	40.1	39.5	38.7	37.6
Low grade	12.2	15.6	19.2	22.9	26.8	30.9	35.2
Total cubic feet	54.3	57.0	60.0	63.0	66.3	69.6	72.8

The required heating surfaces per T. C. H. depend mainly upon the available steam pressures and range from 37.1 square feet at 8 pounds gauge, to 51.5 at 5 pounds, to 60.0 at 4 pounds and to 80.7 square feet at 2 pounds gauge. A ratio of not less than a square foot of heating surface to each cubic foot of capacity is recommended, and if it is at all possible that back pressures are to be reduced below 4 pounds gauge, the additional heating surface should be included, as its cost will be a very small part of the pan installation.

The range for Hawaiian factories is from 23.3 to 98.8 square feet, and 32.8 to 105.2 cubic feet, the average heating surface being 58.7 square feet per T. C. H.

Vacuum Pump Displacement

The accompanying diagrams (Figs. 1 and 2) indicate the desirable vacuum pump capacities for evaporators and pans when using counter current condensers. The average displacement for factories reporting is 32.8 cubic feet per minute, the range 7.41 to 79.40. The desirable capacities in cubic feet per minute per T. C. H. with vacuum of 27″ in counter current condensers are:

	Temperature of injection water—° F.				
	75	80	85	90	95
Pans	14.4	16.8	21.6	28.2	40.2
Quadruple effect	10.5	12.5	15.0	17.0	29.5
Total	24.9	29.3	36.6	45.2	69.7
Pump displacement	37.4	44.0	54.9	67.8	104.4

Since a volumetric efficiency of approximately 67 per cent applies to vacuum pumps under these conditions, the desirable total should be increased by 50 per cent so that the required displacement would be as shown.

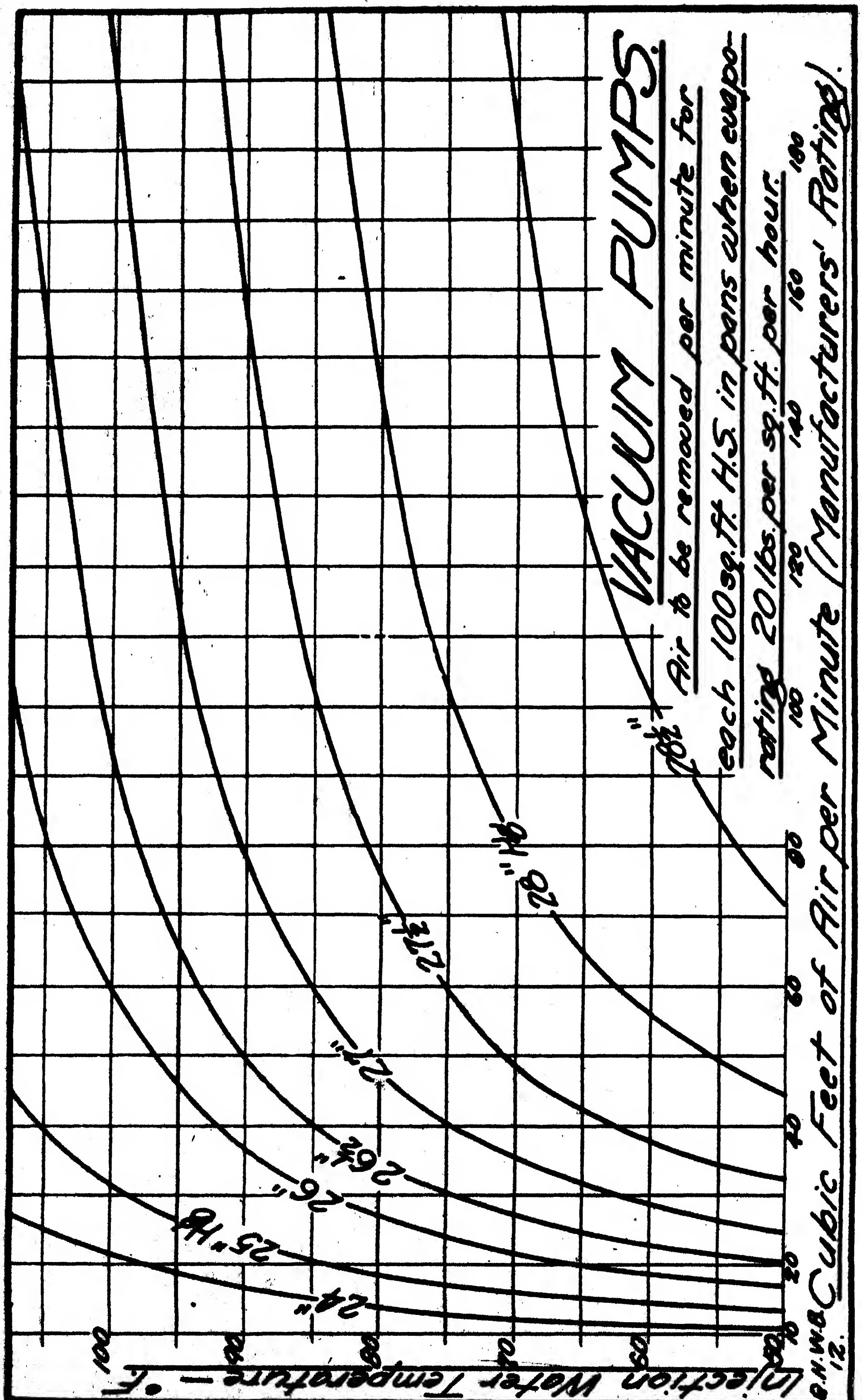
VACUUM PUMPS.
Air to be removed per minute for each 100 sq. ft. H.S. in pans when evaporating 20 lbs. per sq. ft. per hour.
Cubic Feet of Air per Minute (Manufacturers' Rating).
Injection Water Temperature — °F.
24"
25" Hg
26"
26½"
27"
27½"
28" Hg
28½"
0
20
40
60
80
100
120
140
160
180
50
60
70
80
90
100
G.H.W.B.
12.

Fig 1.

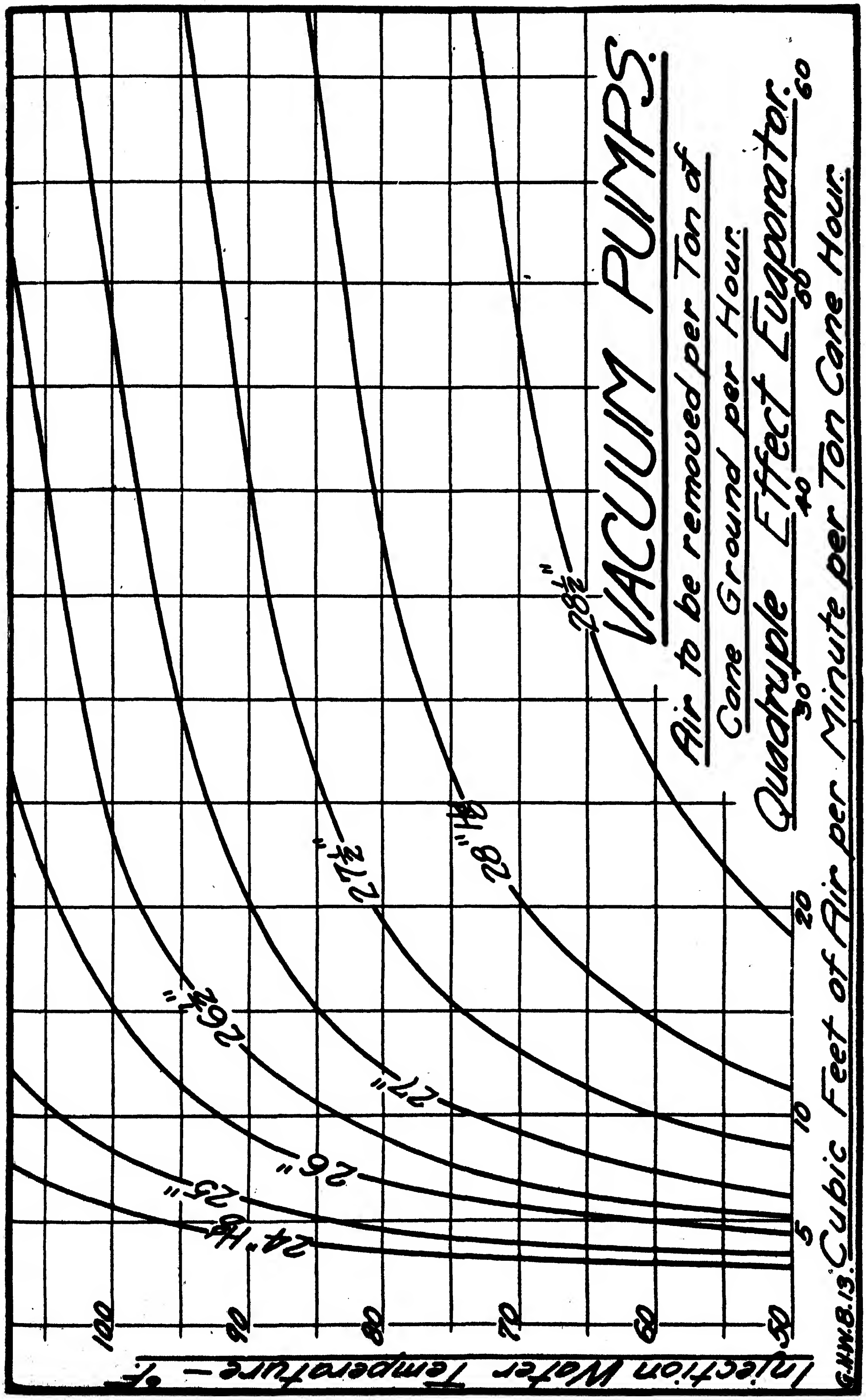
VACUUM PUMPS.
Air to be removed per Ton of
Cane Ground per Hour.
Quadruple Effect Evaporator.
Cubic Feet of Air per Minute per Ton Cane Hour.
5
10
20
30
40
50
60
Injection Water Temperature — °F.
50
60
70
80
90
100
24" Hg.
25"
26"
26½"
27"
27½"
28" Hg.
28½"
G.H.W.B.13.

Fig. 2.

It will be noted that the capacity required varies with the temperature of injection water. Temperatures ranging from 69.8° F. at Paauhau to 110° F. at Olaa have been reported. The latter undoubtedly results when the flume water supply fails during dry years and the cooling pond together with a slight amount of make-up is used at the mill.

Condenser Water Requirements

The accompanying chart, Fig. 3, is based on a 5° F. drop from vapor to tail water in counter current condensers. The 5° F. drop is thought to be ample, as many installations are operating on a 2-3° F. drop and reputable condenser manufacturers design on the basis of a 1.5° F. drop.

Below are the calculated average quantities of water required per T. C. H.:

	Temperature of injection water—° F.				
	75	80	85	90	95
In millions of gallons per day..........	0.0638	0.0740	0.0885	0.1130	0.1542
In gallons per minute..................	44.4	51.5	61.5	78.7	117.4

For triple effect evaporation these figures should be increased by 25 per cent; for triple with a pre-evaporator, increased by 10 per cent, and for quadruple with pre-evaporator, decreased by 11 per cent. The maximum instantaneous demand when placing a pan in service might easily be 60 per cent in excess of the average given.

Crystallizers

Crystallizer capacities range from 161.7 to 492.1 and combined tank and cooler capacities from 491.0 to 1013.5 cubic feet per T. C. H. The capacity required depends upon many factors and may be found from

$$\text{Cu. ft. per T. C. H.} = \frac{3\ PDH \times (S-J)\ (s-M)}{J \times (s-j)\ (S-M)}$$

in which P = Cane polarization.
D = Number of days in crystallizer (including time for filling, emptying and cleaning).
H = Number of hours factory grinds per week.
S = Gravity purity of shipping sugar.
J = Gravity purity of syrup.
M = Gravity purity of final molasses.
s = Gravity purity of second sugar.
j = Gravity purity of second massecuite.

The accompanying chart, Fig. 4, is based on a crystallizer cycle of 12 days, a final molasses purity of 36, final massecuite purity of 55, and second sugar purity of 80. The correction curves at the left indicate the extreme importance of maintaining a low final massecuite and a high second sugar purity. For

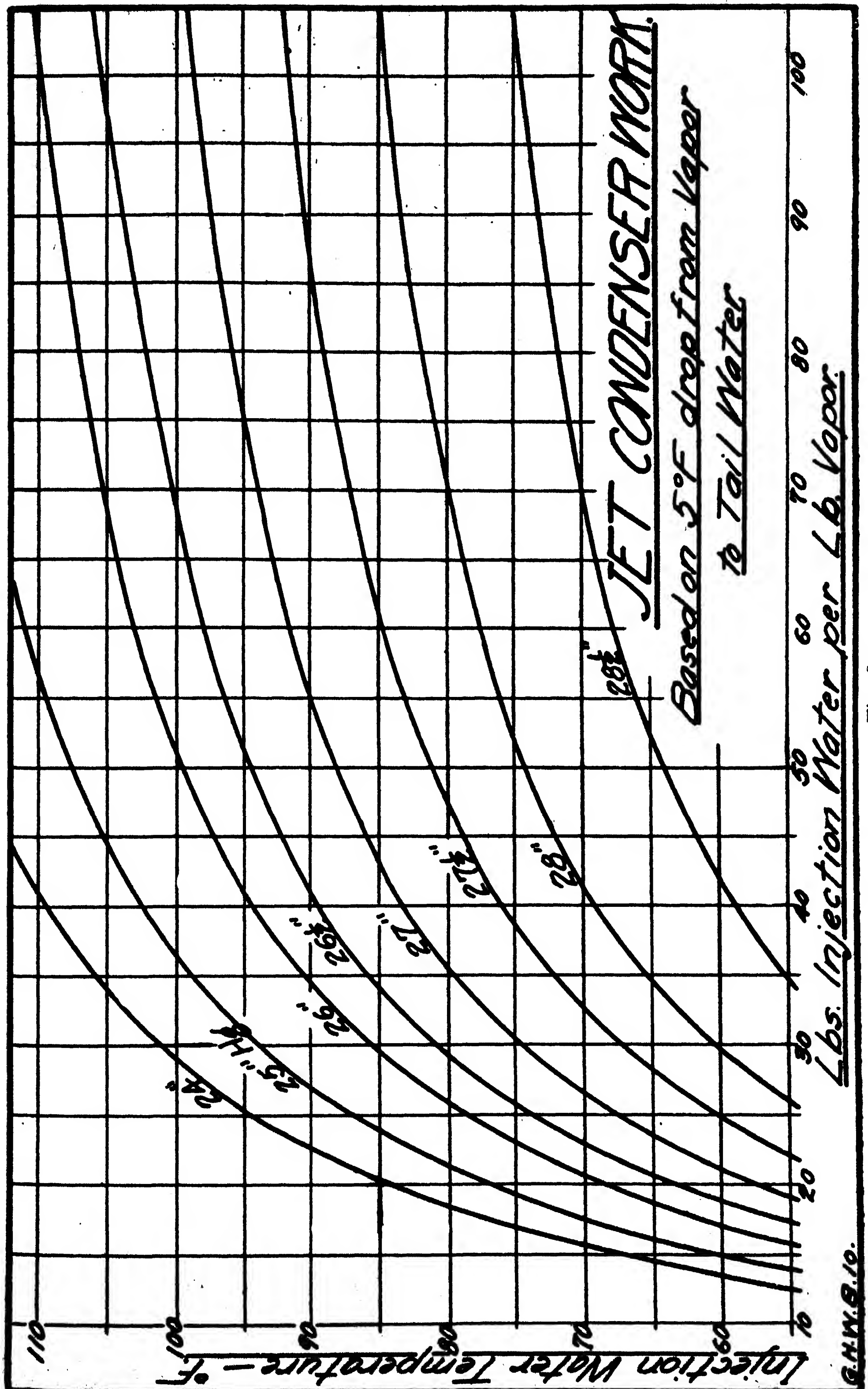
JET CONDENSER WORK.
Based on 5°F drop from Vapor
to Tail Water
Lbs. Injection Water per Lb. Vapor.
Injection Water Temperature — °F.
24"
25" Hg
26"
26½"
27"
27½"
28"
28½"
10
20
30
40
50
60
70
80
90
100
60
70
80
90
100
110
G.H.W. 8.10.

Fig. 3.

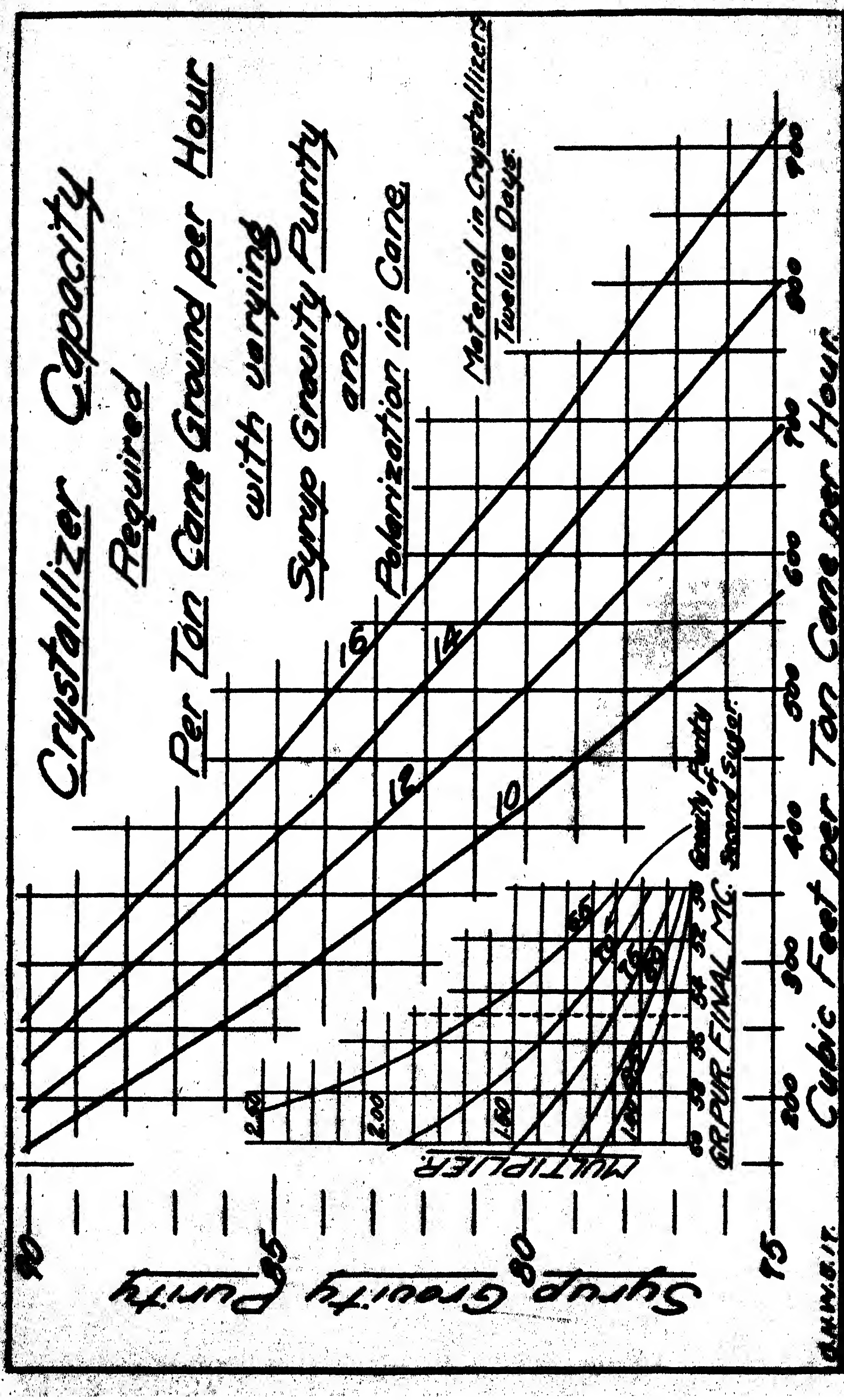
Crystallizer Capacity
Required
Per Ton Cane Ground per Hour
with varying
Syrup Gravity Purity
and
Polarization in Cane.
Material in Crystallizers
Twelve Days.
Cubic Feet per Ton Cane per Hour.
Syrup Gravity Purity
Multiplier.
GR. PUR. FINAL MC.
Gravity Purity of Second Sugar.

Fig. 4.

example, increasing the massecuite purity to 58 and decreasing sugar purity to 70 will increase the quantity of low grade 61 per cent.

It is noticeable that ten of the factories, which, however, produce but slightly over 11 per cent of the Hawaiian crop, are still using tanks and coolers exclusively, holding low grades up to 60 days.

The tendency and modern practice is to boil to grain, and drop to crystallizers where motion is maintained until the possibility of the formation of false grain is past. The water-cooled crystallizer, which has just been developed in the Philippines, promises to reduce this time considerably. In fact, there are some who advocate crystallizers to hold massecuite two days only, the remainder of the cooling being done in tanks without stirrers.

Centrifugals

Screen area in shipping sugar machines ranges from 1.34 to 4.19, in low grade machines from 1.46 to 7.50, and total centrifugal screen area from 3.70 to 9.51 square feet per T. C. H. The requirements when the shipping sugar cycle averages 10 minutes, and the low grade cycle 60 minutes, are as follows:

	Gravity purity of syrup						
	90	88	86	84	82	80	78
Shipping sugar	2.845	2.805	2.760	2.710	2.666	2.612	2.555
Low grades	2.292	2.901	3.568	4.250	4.970	5.745	6.530
Total	5.137	5.706	6.328	6.960	7.636	8.357	9.085

The Baffle Juice Heater*

By Seymour Terry

This subject of the baffle juice heater has been presented before, but the advantages of this design over the old style heater, while not always taken advantage of, are so well assured that it is thought worth while to bring out its good points again. The picture which accompanies this article shows two such heaters in the shops of the Honolulu Iron Works Company, each having 7 tubes per pass, 22 passes and 829 square feet of surface (see Fig. 1). The covers are of cast iron designed on the girder principle and carried by hinges cast with the covers and heads. The heads are made of bronze, which, though of slighty higher first cost, is a safeguard against cracking, the fate of many cast-iron heads. The expensive swing bolts common on the old heater are replaced with standard machine bolts for which sufficient distance is allowed between the head and flanges to enable inserting them from the back. To open the heater door, the nuts are taken off

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and the bolts pushed back, leaving them in place. Cast iron is quite satisfactory for the flanges and steel plate for the shell of thickness to suit the different diameters. The baffle plates (see Fig. 2) are 3/16″ steel plate shelves secured to the shell and arranged to give a decrease of cross section to the steam flow as condensation takes place, thus maintaining an approximately steady velocity of steam. The greater condensation takes place on the lower tubes due to the greater temperature difference at this part of the heater, and the reduction in the number of tubes between baffles gives better tube drainage where it is needed. The tubes are 1½″ O. D. copper No. 16 gauge 15′-0″ long. This is probably the maximum length that can be used without a center support and yet allows of rolling in both heads, which is an advantage over having to use ferrules. In place of the regular electrolytic copper, the tubes can be furnished of a special grade known as Lake fire refined arsenical copper having impurities other than silver and arsenic not in excess of 0.12 per cent, arsenic content to be between .05 per cent and 0.10 per cent. As to the advantages on operation of this heater over the old style, there are two main features:

First: The condensate on the tubes, instead of dripping from tube to tube and so forming a wet coating on the lower tubes through which the heat of the heating steam has to traverse, is collected by the baffle plates and drained to the sides of the heater. When consideration is taken of the fact that in a 900 square feet heater about 12,000 lbs. of water per hour are drained away, this advantage is quite evident.

Second: The heating steam is kept at an effective velocity in a definite direction right through the heater. This steam flow is in part a counter flow to the juice.

Several of these heaters are now in operation in Hawaii. It is generally accepted that the old style heater would heat 60 to 70 lbs. of juice per hour per square foot from 80° to 212° F. with 5 lbs. of heating steam. A baffle heater in the Islands is reported as heating 124 lbs. of juice per square foot per hour with steam at 6 lbs. pressure and juice temperature from 90° F. to 217° F.

The work done by heaters is indicated by the number of the B. T. U.'s transmitted across a square foot of tube surface for each degree temperature difference per minute and is known as the heat transmission coefficient. To facilitate calculations for heaters, the curves in Fig. 3 have been plotted assuming the initial juice temperature to be 80° F. and heating steam to be 0 lb. to 8 lbs. gauge pressure.

The following table gives the old standard heaters at 70 lbs. per square foot per hour and the results from the above mentioned baffle heater. M is the mean temperature difference, B is B. T. U.'s per minute per square foot:

	Pressure of steam lbs.	M	B	$\frac{B}{M}$	Speed through tube ft. per second	Lbs. juice per sq. ft. per hour
Standard heater	5	58.5	138.5	2.36	5.00	70
Baffle heater................	6	53.4	236	4.42	4.96	124

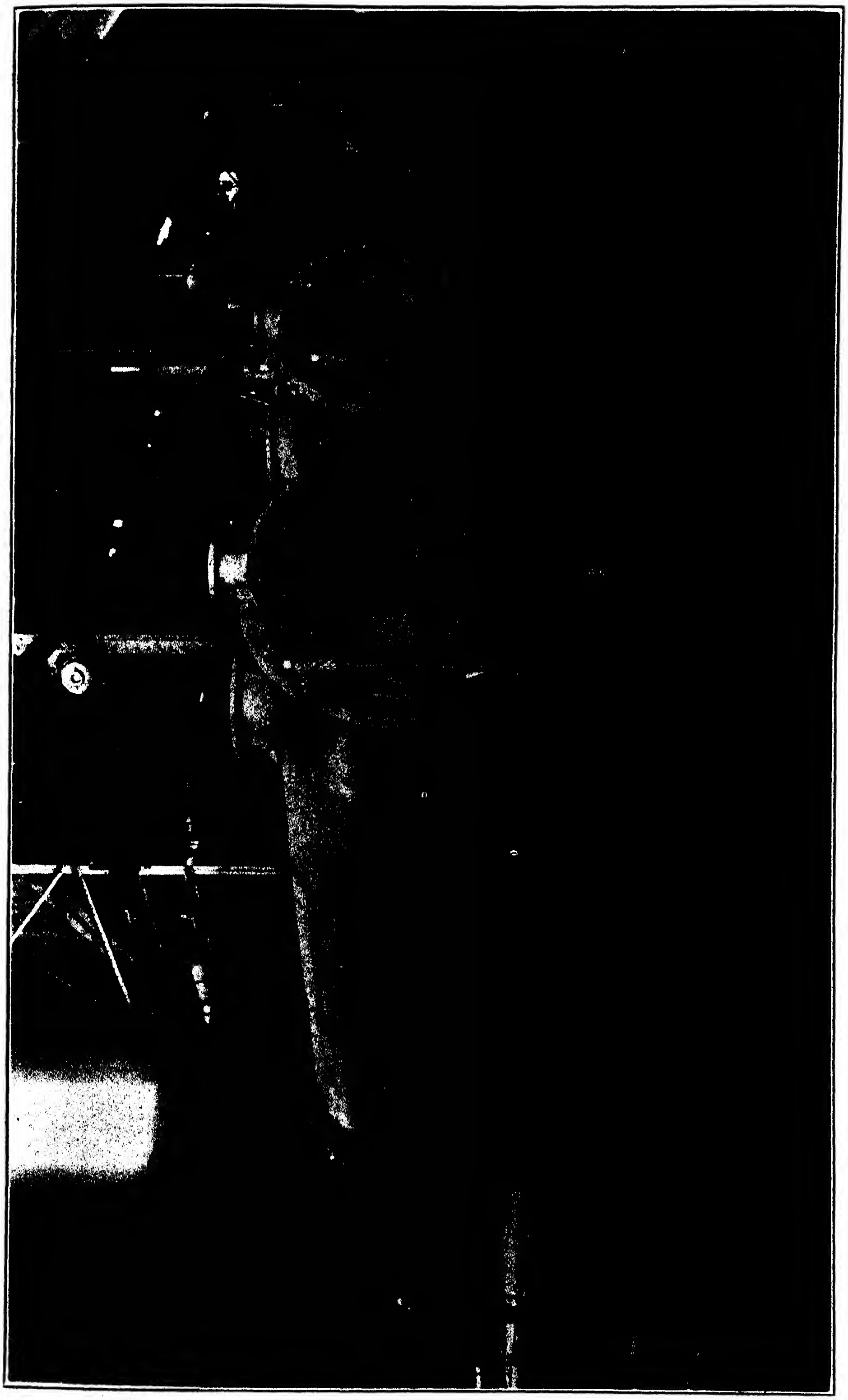

Fig 1.

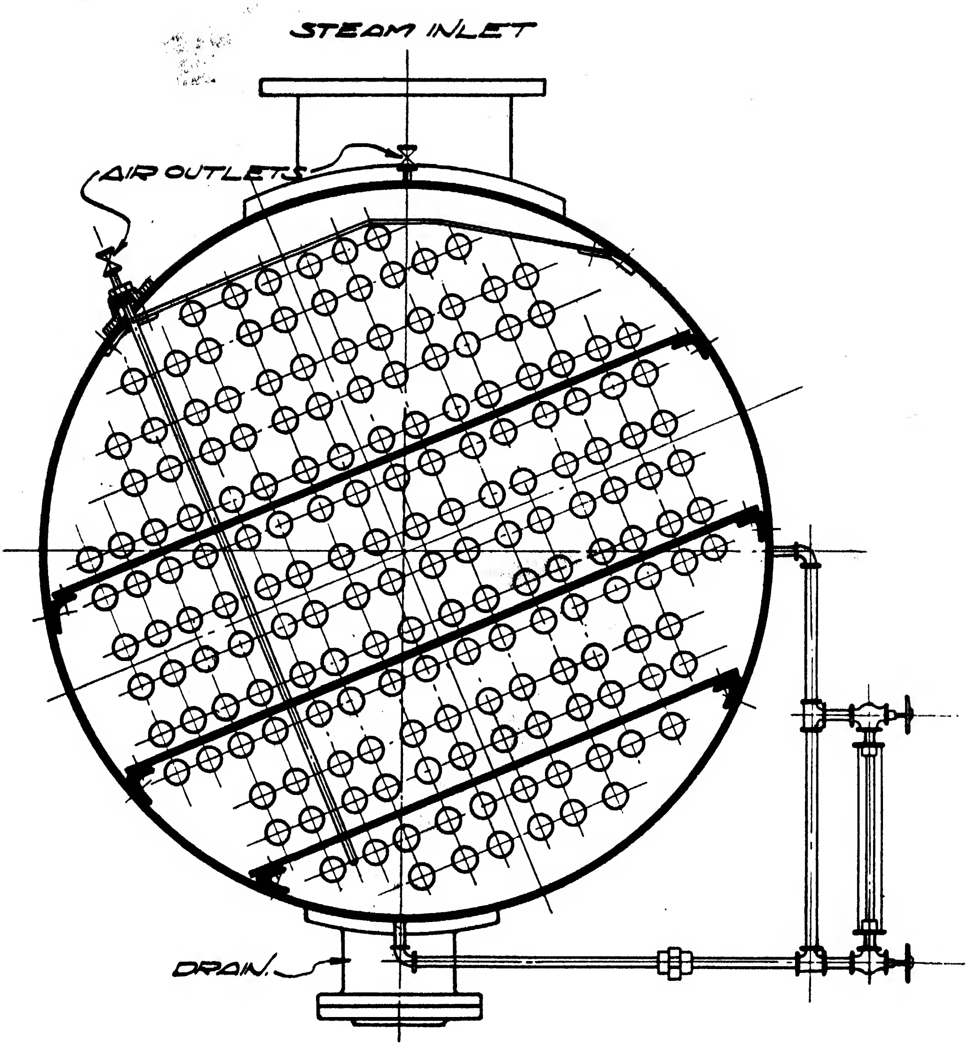

Fig. 2.

$\frac{B}{M}$ — is the heat transmission coefficient.

Juice density 1 = assumed at 65.5 lbs. per cubic foot and specific heat 0.9. No allowance for radiation.

Selection of Heaters

The accompanying table will be found useful in selecting new heaters and when considering the changing over of old heaters to baffle type. The diameter of the shell in the first column gives choice of different numbers of tubes per pass to suit juice tonnage. The table is based on a speed of 5 feet per second in the 22-pass heaters, the juice passing through the tubes in 66 seconds. This time is kept constant for all the heaters, the juice speeds varying with the number of passes, the tonnage with the passes and tubes per pass.

CURVES FOR STEAM PRESSURES

0# TO 8#

JUICE INLET 80° FAH.

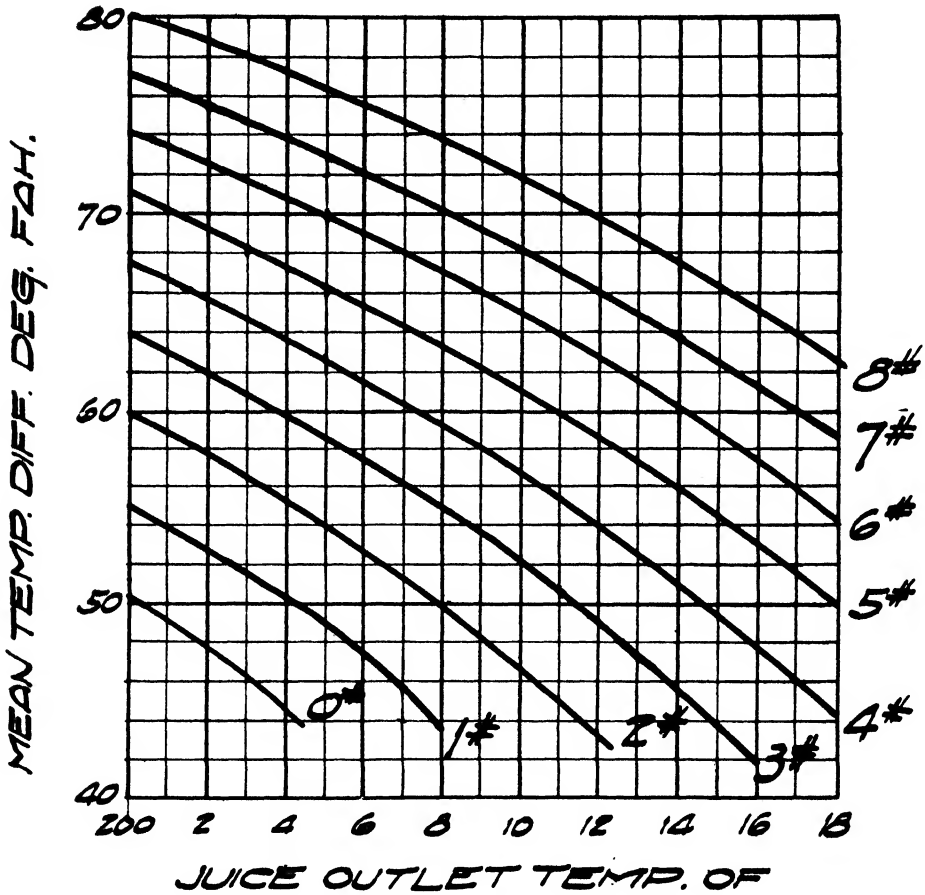

Fig. 3.

BAFFLE HEATERS

Ins. dia. of shell	No. of tubes per pass	No. of passes	Total No. of tubes	Sq. ft. heating surface Ins. tubes	Sq. ft. heating surface Outs. tubes	Tons juice per hour	Speed feet per min.	Time in heater seconds
2′ 7″	3	16	48	258	282	13.2	3.63	66
2′ 7″	4	16	64	344	376	17.5	3.63	66
2′ 9″	3	18	54	290	318	14.8	4.1	66
2′ 9″	4	18	72	387	424	19.7	4.1	66
3′ 0″	3	26	78	420	459	21.4	5.91	66
3′ 0″	4	20	80	430	471	21.9	4.55	66
3′ 0″	5	16	80	430	471	21.9	3.63	66
3′ 0″	6	16	96	516	566	26.3	3.63	66
3′ 3″	4	22	88	473	518	24.1	5.00	66
3′ 3″	4	24	96	516	566	26.3	5.45	66
3′ 3″	5	18	90	484	530	24.7	4.1	66
3′ 3″	6	18	108	580	635	29.6	4.1	66
3′ 6″	4	26	104	560	613	28.5	5.91	66
3′ 6″	5	20	100	538	589	27.4	4.55	66
3′ 6″	5	22	110	592	648	30.1	5.00	66
3′ 6″	6	20	120	646	707	32.9	4.55	66
3′ 6″	6	22	132	710	778	36.1	5.00	66
3′ 9″	5	24	120	646	707	32.9	5.45	66
3′ 9″	6	24	144	775	848	39.5	5.45	66
4′ 0″	5	26	130	699	766	35.5	5.91	66
4′ 0″	6	26	156	839	919	42.7	5.91	66
4′ 0″	7	20	140	753	825	38.3	4.55	66
4′ 0″	7	22	154	829	907	42.2	5.00	66
4′ 0″	8	20	160	861	942	43.8	4.55	66
4′ 0″	8	22	176	947	1037	48.2	5.00	66
4′ 3″	7	24	168	904	990	46.0	5.45	66
4′ 3″	8	24	192	1033	1131	52.6	5.45	66
4′ 6″	7	26	182	979	1072	49.8	5.91	66
4′ 6″	8	26	208	1119	1225	57.0	5.91	66

Copper tubes 1½″ O. D. No. 16 Stubb's gauge 15′ 0″ long. Lbs. of juice per sq. ft. per hour 102.

The pounds of juice per square foot per hour are 102 in all cases. If, in the heaters where the speed is 5 feet per second, it is assumed that a steam pressure of 5 lbs. gauge will heat the juice from 80° F. to 212° F., then the mean temperature difference is 58.5 and the B. T. U.'s per square foot per minute are 203, giving a heat transmission coefficient of 3.47.

Assuming heat transmission coefficients to vary as the cube root of the juice velocity, curve 3 has been plotted giving heat transmission coefficients for juice velocities from 3 to 8 feet per second with 5 feet per second and $\frac{B}{M} = 3.47$ as a base (see Fig. 4).

By the use of these curves, the effect of a change in juice velocity from the assumed standard of 5 feet per second can be found. For instance, the 8-tube per pass 26-pass heater has a table velocity of 5.91 feet per second. From curve 3 the heat transmission coefficient is 3.67; this divided into the B. T. U.'s per

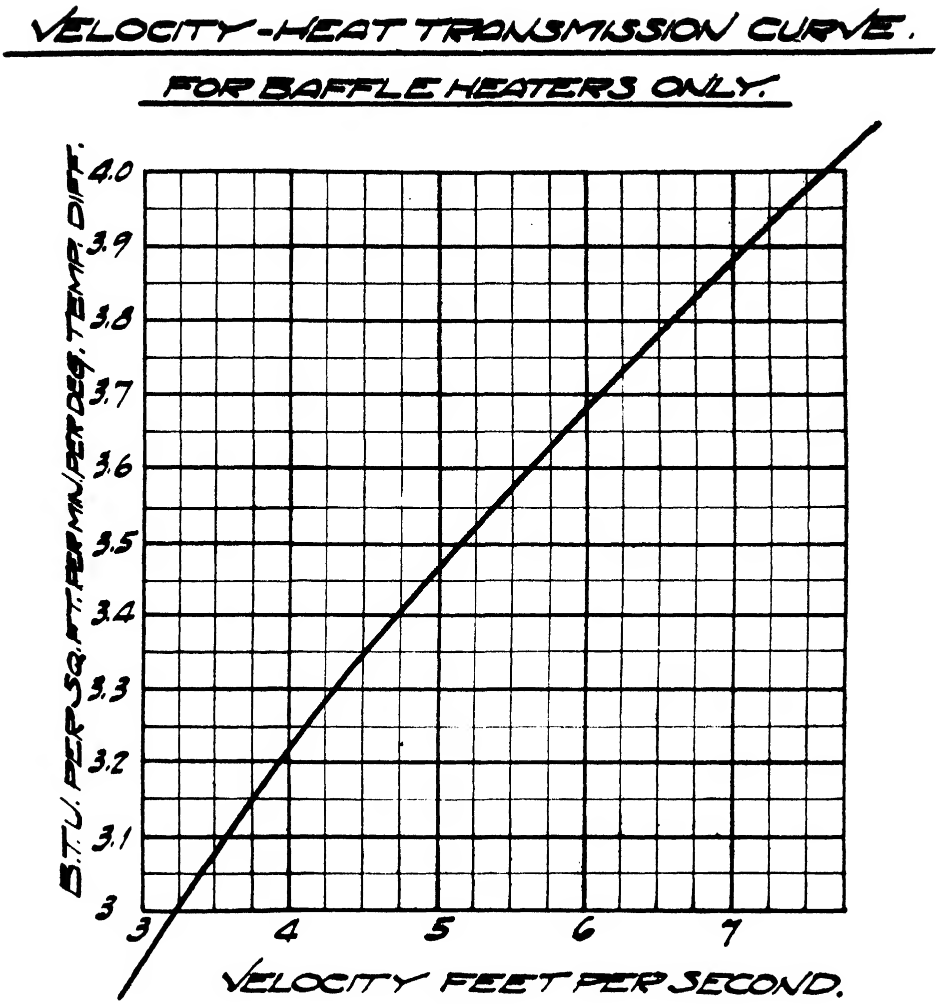

Fig. 4.

square foot per minute of 203 gives a mean temperature difference of 55.4. By now referring to curve 2 with a juice temperature from 80° to 212° F., the steam pressure required will be 4¼ lbs. gauge. If the juice tonnage is changed from that given in the table, then the heat transmission of 203 will change in proportion. For instance, if the 8-tube per pass 26-pass heater had 50 tons in place of 57, then the heat transmission would be 177 B. T. U.'s per square foot per minute and the velocity 5.18 feet per second. From curve 3, the heat transmission coefficient is 3.51 which, divided into 177, gives 50.4 mean temperature difference. From curve 2 a steam pressure for juice at 212° F. is about 3¼ lbs. Under this condition, the juice is 75 seconds in passing through the tubes.

In the case of the slow velocity heater, when increasing the tonnage, the steam pressure will have to be increased. Taking the 7-tube 20-pass heater at 38.3 tons and 4.55 feet per second, increased to 50 tons and 5.92 feet per second,

gives a heat transmission of 265 B. T. U.'s and a coefficient of 3.67, which is a mean temperature difference of 72.2 and from curve 2 a steam pressure of 8¼ lbs. In this case the time of the juice in the heater is 50.5 seconds.

A Brief Sketch of the Development of the Saccharimeter*

By F. T. DILLINGHAM

By plane-polarized light is meant light all of whose vibrations lie in a single plane.

The polarization of light was first noticed in 1678 by Huygens while studying the refraction of light in a crystal of Iceland spar. In 1808, it was discovered that polarization could also be produced by reflection.

If a beam of light falls upon a smooth surface of a transparent substance it is decomposed into reflected and refracted rays. The reflected rays at a definite angle of incidence are completely polarized, the plane of the lines of incidence and reflection being the plane of polarization. The angle of incidence at which reflected light is completely polarized is called the polarizing angle and varies according to the refractive power of the reflecting substance. The polarizing angle of glass of refractive index 1.54 ($n = 1.54$) is about 57 degrees. (Fig. 1.)

Of several devices which are available for producing plane-polarized light, a modified crystal of Iceland spar or calc spar is the only one used in the construction of polariscopes and saccharimeters. Calc spar is a pure, crystallized form of calcium carbonate. It is very soft (number three in the scale of hardness), and easily decomposed by the action of heat and acids; hence great care must be taken to handle Nicol prisms gently. Calc spar is a clear, transparent mineral which easily cleaves into rhombohedral prisms. If a small object is examined through such a rhombohedron, the image will be seen as doubled. Rays of light in passing through the crystal undergo double refraction, that is, they take two paths through the crystal. This phenomenon is noticeable in any position of the calc spar rhombohedron except in a direction parallel to the diagonal, joining the two opposite obtuse corners, known as the optical axis of the crystal. (Fig. 2.)

Before a crystal of calc spar can be used in the construction of a polariscope it must be modified so as to eliminate one set of the component rays. The best known method of so doing is as follows: A rhombohedron of calc spar, ABCD, is selected, the length of which is about three times its width. At each end of the crystal, wedge-shaped sections, ADE and BFC, are removed in such a way as to reduce the acute angles DAB and BCD from 71 degrees to 68 degrees. That is, the end faces of the crystal are ground and polished so they make an angle of 68 degrees with the long edges instead of 71 degrees of the original crystal. Then the crystal is cut in halves or ground along a plane passing through one of

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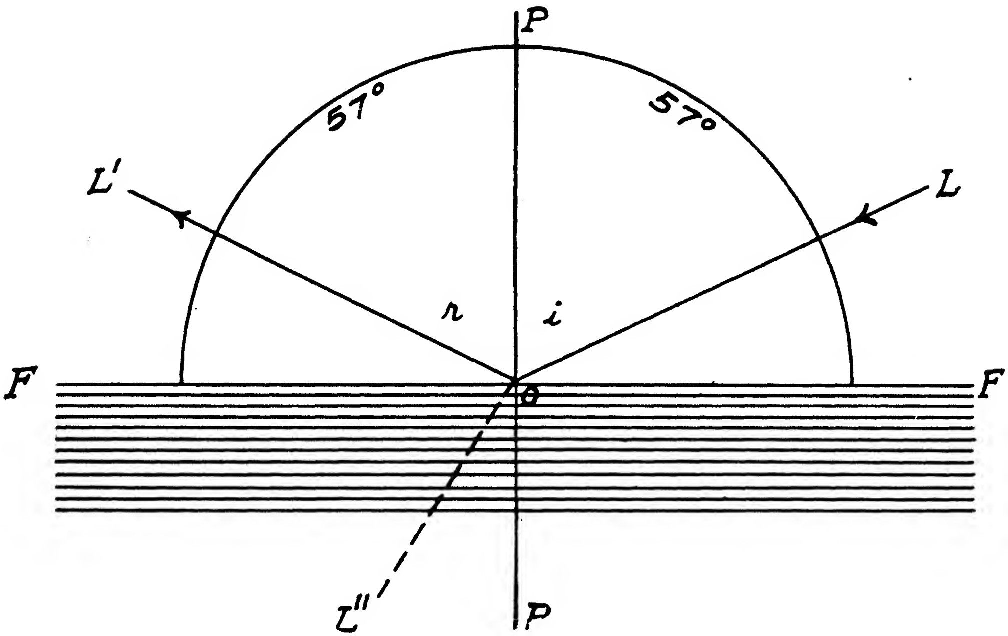


Fig 1.

the obtuse solid angles of the prism and perpendicular to the two modified end faces. The cut or ground surfaces are then polished and cemented together with Canada balsam. The long sides of the prism thus obtained are next blackened and the prism mounted by means of cork or wax in a metal tube. Such a prism is known as a Nicol prism. (Fig. 3.)

Let AFCE represent a principal section of the Nicol prism. A beam of light entering the prism parallel to the long side is resolved into two component rays. One is the ordinary ray, TRO, which is the component most refracted, and it meets the balsam film, EF, at such an angle that it is completely reflected to the side of the prism where it is absorbed by the black coating. The other is the extraordinary ray which is less reflected, and, passing through the film of balsam, emerges in a polarized condition from the end surfaces of the Nicol prism at the point P (Fig. 4). Light in such a condition is said to be plane-polarized.

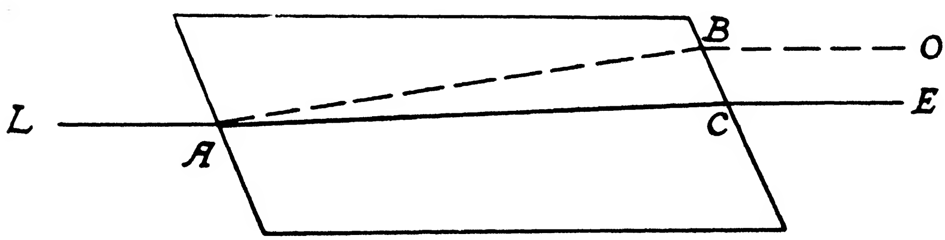


Fig. 2.

Looking through two Nicol prisms at any course of light, holding the prisms in such a way that the light will pass through each successively, and revolving one slowly on its long axis, it will be noticed that the light seen through the prisms varies in intensity as the prism turns. At certain points in the revolution of the prisms, 180 degrees apart, no light passes; while at exactly midway between these positions (90 degrees from them), the most light is seen. As one prism is revolved the light increases up to a maximum, and then decreases until a point of total extinction is reached. Consequently the amount of light passing

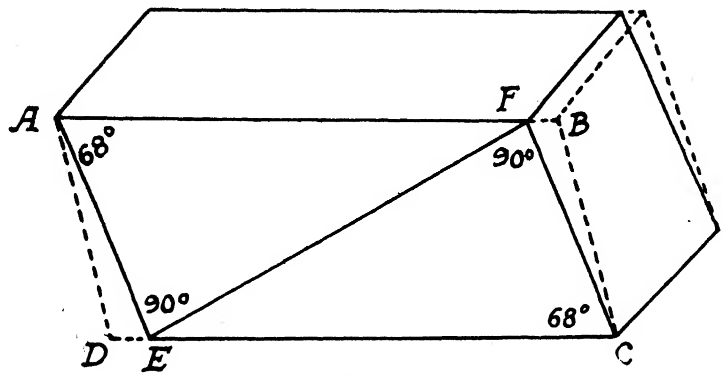


Fig. 3.

through such a combination of Nicol prisms depends on the angle through which one of the prisms is rotated from the positions of maximum or minimum illumination. The relative position of the Nicols showing maximum light intensity is that point of rotation when the rhomboids of the end faces are parallel, each edge of the end face of one prism to the corresponding edge of the other prism. When one of the Nicols is then rotated to a position 90 degrees from this, no light passes and the field is dark. In the first case the Nicol prisms are said to be parallel and in the second case they are said to be crossed.

If the combination of prisms as just described is held in a suitable apparatus, one prism being fixed and the other capable of rotation, a measuring device can be attached to the rotating prism and these phases of light intensity can then be referred to points on a scale. Such an instrument is called a polariscope and can be utilized in sugar analysis. A sugar solution placed between the prisms in such

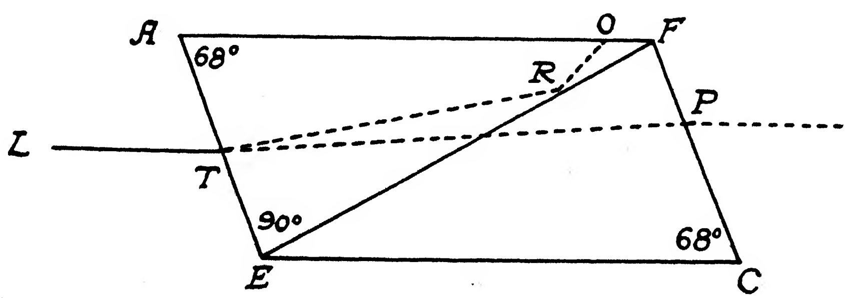


Fig. 4.

a way that the light passes through it in its travel between the prisms, affects the intensity of the light so that it is necessary to rotate the movable prism to restore the light effect shown by the polariscope previous to the insertion of the solution. The magnitude of the angle through which the prism must be rotated to restore the original light effect is found to depend directly on the concentration of the sugar solution and, hence, can be taken as a measure of the sugar itself.

Such a combination of two Nicol prisms constitutes the essential feature of every polariscope. The fixed prism is called the polarizer and the movable one the analyzer.

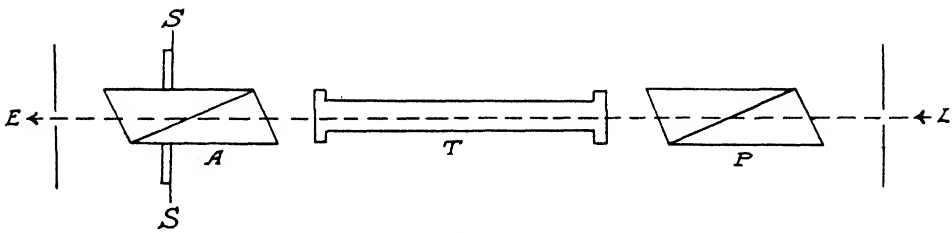


Fig. 5.

The construction and principle of the simplest form of polariscope can be seen by means of a simple diagram (Fig. 5). P is the polarizer, consisting of a stationary Nicol; and A is the analyzer, consisting of a movable Nicol mounted in a revolving sleeve. The angular rotation of A is measured upon a graduated scale, S. L is a source monochromatic light which passes through the instrument to the eye of the observer at E. If the Nicol A is crossed with respect to the Nicol P, the point of extinction of light will then mark the zero point on the scale, S. If now a tube, T, filled with a solution of sucrose is placed between P and A, the plane of polarized light coming from P will be rotated from its original position and the light will be no longer entirely extinguished in A. By rotating A the point of extinction is again reached. The angular rotation produced by the solution in T is then determined on the graduated scale. Because the light rays of different wave lengths which make up white light are rotated to different extents by optically active substances (a phenomenon known as rotation dispersion) it is necessary to use a monochromatic light (e. g., a sodium flame) for this type of polariscope.

One of the first polariscopes to be constructed was one made by Biot in 1840. It was of the simple type just described except that it had an adjustable mirror of black glass for the polarizer and a modified prism of calc spar for the analyzer. The essential features of this early instrument are retained in the modern polariscopes, but in a modified form. In the Biot polariscope the point of total extinction of light constituted the end point; but, as experiment with such an instrument will show, it is impossible to determine the exact point of extinction without a large error, that is, the end point is not sharp.

In the various optical devices for producing a more exact end point, much ingenuity has been manifested; as a matter of fact, these devices alone constitute

the essential differences between most of the different makes of modern polariscopes for measuring angular rotation.

In 1844, the Biot instrument was improved by discarding the polarizing mirror and employing a polarizing Nicol, the optical parts being arranged as shown in the preceding chart (Fig. 6). The most important improvement of this instrument was in the end point. Here a vertical, broad, black band in a light field marked the zero point.

Another end point device used in the earlier instruments was the transition tint quartz plate. Sections of quartz cut perpendicular to the optical axis of the crystal have a strong rotatory effect on plane-polarized light when the light passes through parallel to the optical axis, some crystals being dextro-rotatory and others levo-rotatory. The amount of rotation depends on the thickness of the quartz section.

The transition tint plate consists of two plates of quartz of equal thickness, one of which rotates the plane of polarized light to the right and the other to the left. The plates are cemented together at their edges and carefully ground and polished. These are mounted in such a way that each section covers half of the optical field of the polariscope. If such a plate is placed between two parallel Nicol prisms and examined with white light, the light in passing through such a combination is found to be deprived of its yellow rays, and the field will now show the resulting complementary tint, usually described as a rose violet. If the analyzer is turned to the right or the left the uniform rose color of the plate will change to contrasting tints of red and blue as seen in opposite halves of the field. If a solution of an optically active substance is placed in a tube in front of the plate the uniformity in color of the transition tint will be destroyed, and the two halves of the field will be differently colored. Rotating the analyzer to the point where the transition tint is again produced will give a measure of the angular rotation of the solution.

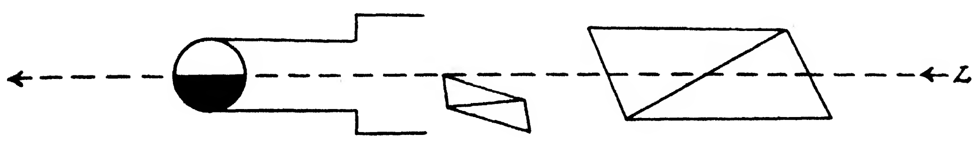


Fig. 6.

In order to overcome the defects of the instrument just described, Jellet constructed the first half-shadow polariscope in 1860. Jellet's half-shadow device consists of a rhombohedron of calc spar with its ends cut square and bisected lengthwise by a plane forming a small angle with the axial plane of the prism; the two halves are then cemented together in reversed position, the result being that the axial planes of each part are no longer parallel but are tilted toward one another at a slight angle. This modified prism is placed between the polarizer and the analyzer with its line of union bisecting the field. In this case rotating the analyzer until it is crossed with the polarizer will not produce total extinction, but a uniform shadow.

The Jellet prism was further modified by Cornu giving what is known as the Jellet-Cornu prism. This was made by bisecting a Nicol prism lengthwise by a plane passing through the shorter diagonal of the end face. A small wedge-shaped section was then removed from each cut surface and the two halves reunited. This split prism combines the effect of an ordinary Nicol and a Jellet prism. The removal of the two wedge-shaped sections causes a tilting of the polarizing planes of the two halves of the prism so that they make an angle of about 175 degrees with each other.

The modified prism is used as a polarizer and is mounted in the polariscope, with a diaphragm having a circular opening between it and the analyzer, in such a way that the opening is bisected vertically by the line of the joint of the two halves of the prism. If the analyzer is turned to a position which would give the total extinction for an instrument fitted with an ordinary Nicol for a polarizer, the field made by the diaphragm opening will not be black in this case, but faintly and evenly illuminated, appearing as a luminous disk. The slightest rotation of the analyzer from this position will produce a shading in one or the other half of the field.

The Lippich half-shadow polariscope uses a small Nicol or "half-prism" for its shadow device. This small Nicol is placed between the polarizer and the analyzer, close to the polarizer, in such a position that it covers half of the field. The polarizer is mounted in such a manner that its plane of polarization makes a slight angle with that of the small Nicol.

The value of the polariscope for the determination of sucrose was quickly recognized in commercial work, and instruments were specially designed to reveal the sugar content of industrial products by a simple and more direct way than by the use of the ordinary polariscope. Such instruments are known as saccharimeters and have scales graduated in divisions expressing percentage by weight of sucrose instead of angular degrees.

In commercial work, where many rapid polarizations have to be made, sodium light is inconvenient to maintain and trying on the eyesight; and, owing to the unequal rotation dispersion of light rays of different wave lengths by optically

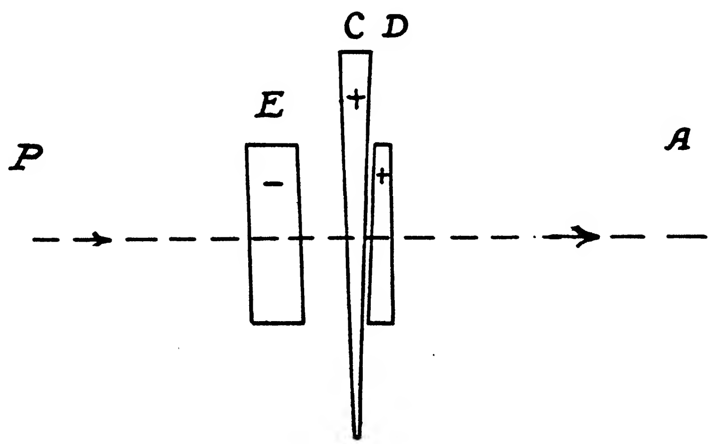


Fig. 7.

active substances, it is not feasible to employ a saccharimeter with a rotating analyzer if the light used is white or compound in nature.

The problem of devising a saccharimeter for use with ordinary lamp or day light was solved in a most ingenious manner by the quartz-wedge compensator, which was invented in 1848 by the French physicist Soleil, who found that the rotary effect of sugar solutions could be exactly neutralized by a plate of optically active quartz of the proper rotation and thickness.

In a quartz-wedge saccharimeter the polarizer and analyzer are both stationary. The rotation of the solution is measured by shifting a wedge of optically active quartz between the sugar solution and the analyzer until the rotation of the wedge system at a certain thickness exactly neutralizes or compensates the rotation of the sugar solution. By means of a scale attached to the quartz-wedge the rotation of the sugar solution is given in per cent.

The selection of quartz for compensation is based upon the fact that it has almost the same rotation dispersion as aqueous solutions of sucrose, but in the opposite direction; that is, a section of optically active quartz and a sucrose solution of equal rotation for light of one wave length will have very nearly equal rotations for light of all other wave-lengths. The small disturbances due to the light difference in rotation dispersion between sugars and quartz may be removed by means of a light filter.

The quartz wedges used in the construction of saccharimeters are cut perpendicular to the optical axis of the quartz crystal; they may be either of dextro- or levo-rotatory quartz, the method of mounting the wedge depending upon the character of the rotation. This can be seen by reference to a diagram (Fig. 7).

PA represents the passage of light through the instrument along its axis, the analyzer being at A and the polarizer at P. C and D are two wedges of right rotating quartz which are movable by being slid past each other in a direction at right angles to the axis of the instrument. Together these two wedges make a section, the thickness of which can be changed readily by moving one or both of the wedges. E is a section of left-rotating quartz. When the combined thickness of C and D equal that of E, the opposite rotating effects of the two wedges and the section E balance, and the scale of the saccharimeter attached to the wedges reads zero. If, now, a tube containing a sucrose solution is placed in the instrument between the polarizer and the compensator, it will be necessary to decrease the thickness of the right-rotating section made by the wedges by sliding them by each other outward till the left rotatory effect of the section E balances the combined effect of C, D, and the sucrose solution. From the scale the percentage of sucrose or the percentage polarization may then be read directly.

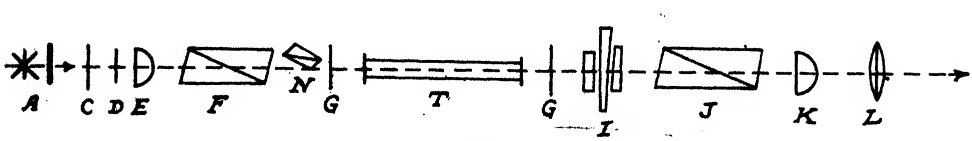


Fig. 8

The final diagram will give some idea as to the arrangement of the various parts of the modern saccharimeter (Fig. 8).

A, is the source of light.
C, a cover glass.
D, a light filter.
E, a condensing lens.
F, the polarizer.
N, the end point device, a small Nicol.
G, splash glasses.
T, a tube for sugar solutions.
I, a quartz-wedge compensator.
J, the analyzer.
K, L, lenses of the telescope.

Mill and Boiling House Machinery*

By J. Lewis Renton

Multiple Knife Sets

Quite an interest is being taken just now in improving the knife sets for preparing the cane for crushing. Aside from the set with only a few knives attached, which can be considered a leveller, the multiple knife set is an aid in extraction and increased capacity for the same reasons that the shredder is. The shredder is more thorough and, therefore, the results are more apparent.

Mr. Meinecke was probably the originator of the multiple knife sets and he now offers an improvement on his original design. The heavy blade holders now used do away with breakage, as the holders can be made of a very tough steel instead of a tool steel which is more or less brittle. The blades are small, cheap, reversible, easily replaced, and on account of their size and support, can be made of good steel and properly hardened.

Messrs. Hind, Hall and Kopke, have gone a step further with their patented knife set and inserted renewable blades. These blades are revolved by removing bolts and changing the blade a quarter turn to a new cutting edge. The improvements claimed for this design over the original Hind hubless revolving knives are as follows:

1. The cutting edge can be renewed without removing the blade from the shaft.
2. Shaft can be revolved in either direction without changing the blade.
3. The flywheel effect of this design is much greater than in any knife arrangement where the knife comes to a point at its outer end.

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

4. The cutting edge presented by the disc is very effective; it has a sliding cutting action, as the edge in contact with the cane is the outer extremity of the knife.

5. The construction of the improved knife is much stronger than the original blade.

6. These blades can be used interchangeably with the old type of Hind hubless blade.

W. A. Ramsay offers an improvement of the swinging type of knife set presented by him some time ago. This set retains all of the advantages claimed for the previous design and now adds simplicity of construction in its manufacture. No knife hubs or holders are necessary, merely doing the necessary drilling and tapping to a length of square shaft, the ends, of course, being turned for journals. The swinging feature prevents breakage by swinging away from obstructions and centrifugal force, and at other times holds the knives at right angle to shaft.

Anyone using the multiple knife sets soon observes that practically all of the wear comes on the three or four inches comprising the tip of the blade. At Ewa, the old Meinecke principle has been retained. The hubs have been increased in diameter to reduce the knife overhang and the knives shortened a corresponding amount while increasing the width of the blade from 4½ to 6 inches. This makes a very rugged blade, but is subject to some breakage.

A. Anderson, of Papaikou, is using very hot water from his boiler feed line to wash down with, every six hours, in and around the mills, and reports very good results. Ewa installed an all-metal juice strainer a year ago, and using this strainer with hot water for washing down is getting results. The hot water is procured by running tap water through a discarded high pressure injector. Mr. McCleery stated that the acidity tests throughout the mill trains showed a big improvement and he was of the opinion that a strong force of good hot water was the best method yet developed to hold this loss in check.

Lubricators

One often wonders, when steam cylinder lubrication and oil in boilers are discussed, why more thought is not given to force feed cylinder oil lubricators. In one case, it was found that the heater pump was using as much cylinder oil as the main mill engine, both being equipped with hydrostatic lubricators. This is not to be wondered at when it is realized that the main engine usually has a competent mechanic in charge who is responsible for the oil used, while the heater pump is fed cylinder oil as fast as the container becomes empty, usually by someone snatching a minute or so from the scales or settling tanks to do it.

Anyone who has tried setting hydrostatic lubricators appreciates the difficulties. If the night is cool, the oil becomes more viscous and the flow is less, no matter at what temperature the oil was put into the lubricator. If you spend a week adjusting it, the chances are that if you came around a week later, the lubricator would be out of adjustment.

A satisfactory force feed lubricator can be purchased for about double the price of a hydrostatic lubricator, or for $22.50, to be exact. They will save enough oil to pay for themselves. Also, the less cylinder oil used means just

that much less oil to keep out of the boilers. This is probably the most important consideration of all.

Some of the good points of a force feed lubricator are:

1. The oil is fed in small increments, resulting in a slow change, if desired. They are also capable of close adjustment.

2. The lubricator, when once set, is not apt to be altered, as tools are necessary.

3. The amount of oil forced into the cylinder is in proportion to the speed of the apparatus.

4. The flow stops automatically when the piece of apparatus stops.

Elimination of Oil in Boilers

George Duncan, of Olaa, has contributed the following:

This is a subject which has received quite a little attention in several sugar factories throughout the Territory within the last few years, more especially since the inauguration of the Bureau of Boiler Inspection by the Hawaiian Sugar Planters' Association. This does not mean that the evil did not exist previous to that time, but simply that more publicity and attention have been given it since being brought to the notice of the various mill employees by the boiler inspectors.

The danger of allowing oil to enter the boilers is realized by nearly everyone, yet there are a few, who for some reason or another, will not sanction the purchase of the necessary apparatus for its elimination. Perhaps these few cannot be altogether blamed, in a way; it may be that those whose duty it is to make the recommendation have failed to do so, either through ignorance of the existing danger, or perhaps on account of there being installed already, some antiquated arrangement which does not do the work.

The cost of the necessary apparatus for the successful elimination of oil from boilers is infinitesimal when compared with the cost of repairs to them due to the presence of oil. When oily feed water is used, the oil adheres to the heating surface and forms a coating. Oil being a poor conductor of heat, the coating acts as an insulator and reduces the rate of transmission of heat. When the boilers are being worked at or near their capacity, overheating of the heating surfaces takes place, with consequent bagging and possible rupture of the tubes and plates, which might cause a disastrous explosion.

Different methods for extracting the oil from the feed water are used in the various factories. Some separate it from the steam before it goes to the evaporators, vacuum pans, etc.; some attempt to remove it from the feed water after leaving the hot-well; and others make little or no attempt to remove it at all.

As almost all of the exhaust steam is used in the heating and boiling of the juices in sugar factories, the logical method for the removal of the oil would therefore be the first named one, i. e., separating it from the steam before reaching the various boiling apparatus. It is just as bad having the heating surfaces of the tubes in an evaporater covered with oil as it is in a boiler, the only difference being the loss in heat transmission in the evaporator and the consequent lowering in efficiency of the apparatus.

There are various types of separators on the market for separating the oil from the steam, but a very efficient type is one that is built locally for this purpose. It consists of a steel drum closed at both ends, about 3′ 6″ diameter and about 8′ 0″ long. The drum lies horizontally and there are two openings in it, both the same size as the exhaust pipe. The inlet opening is in the center of one of the heads, the outlet being at the other end but through the shell, on the top. Inside the drum is a deeply ribbed cast-iron plate, placed 6″ in front of the inlet. This plate is open at the sides and bottom, but closed at the top. The entering exhaust steam impinges against the ribbed plate, then passes to the outlet, through the openings between the shell and sides of the plate. The ribs of the plate, being

at right angles to the direction of flow of the steam in its passage from the inlet to the openings between the shell and plate, act as retainers for the oil collecting on the plate, until it drains to the bottom of the drum. From there it is drained off by a 2″ pipe in the bottom of the drum at the outlet end. This apparatus does all that is claimed for it.

The method of extracting the oil from the boiler feed water after leaving the hot-well is done by feed water filters. There are various types, but two seem to predominate; one in which excelsior is used as the filtering medium, the other in which Terry cloth or Turkish towelling is used. They may do the work that is claimed for them, but as the filtering medium has to be removed and cleaned at least once a week, the cost of their operation is high in comparison with the steam separator, which requires no attention whatsoever except to see that the drain pipe is kept open.

It has been observed at the cleaning of a feed water filter, connected to the surface condenser of a steam engine, that not 20 per cent of the cylinder oil fed to the engine was to be found on the filtering cloth. It must therefore be assumed that a large portion of the oil found its way through the cloth and incidentally into the boilers.

There is no doubt that the ideal installation would be an oil separator, placed ahead of the boiling and evaporating apparatus, and a feed water filter in the feed line. In that case it would be practically impossible for any oil to ever find its way into the boilers.

The quality of cylinder oil to be used in a sugar factory is an important question. It is false economy to use cheap brands. As has been proved, more than 50 per cent saving in the consumption of oil can be obtained by the use of a high grade quality, than can be by the use of one at half that price. Why not use the expensive oil and give the separators and filters less work, when the yearly cylinder oil expense can be kept at or near the same amount as when the consumption of the cheap oil is more than double that of the former?

A. W. Dunn, of Honomu, describes the method of eliminating oil at Honomu Sugar Company, through the employment of a counter current surface condenser, as follows:

According to the method now generally practiced in sugar factories, the exhaust steam from all the various engines and pumps is utilized for boiling sugars and sugar juices. The condensate from the various elements of sugar-making apparatus is drained into a hot-well and thence fed into the steam boilers. This method is objectionable for the reason that the exhaust steam from the various engines and pumps carries more or less cylinder oils, consequently the condensates from the various pre-evaporators, juice heaters, and vacuum pans (which are operated by exhaust steam) are impregnated with cylinder oils, which enter the boilers.

The presence of oil in boilers renders same dangerous, reduces boiler efficiency and causes leaky boilers, entailing costly repairs.

The system now in operation at Honomu prevents lubricating oils from entering boilers and keeps the heating surfaces free from oil, as the greasy condensates are taken into a condenser and utilized as heating agents to raise the temperature of the fresh water supply or "make-up."

From the foregoing it will be seen that there has been provided a very simple arrangement whereby oily condensates are exchanged for an uncontaminated feed water supply without material loss of temperature in the feed water entering boilers.

This system has been in operation at Honomu mill for the past seven months, and, at the close of the grinding season, the boiler inspector reported boilers free from oil.

Boiler Room

Boiler Installations: There have been so many excellent papers presented on the Boiler Room that it is difficult to present a paper. A. G. Budge's (1) paper on Boiler Room Equipment and Operation covers the requirements of a perfect steam boiler and the selection and operation of boilers.

"Practical methods of comparing the results obtained when burning bagasse as fuel," by Mr. Horace Johnson (2) is worth studying.

Leaving these subjects out, it will be endeavored here to study the design of boiler installations and the factors governing the relation of the boiler to the grate, furnace and stack.

The function of the grate and furnace is to completely consume the combustible with a minimum of excess air, and be of such a size that enough hot gases are passed on to the boiler to produce the rating desired. The size of the boiler, then, should determine the grate area, which in turn determines the furnace volume. The draft will vary these considerations, but will, at present, be assumed to be uniform.

Boilers: It would seem logical, then, to study the factors covering the size and rating of boilers.

There always has been and still is considerable discussion on the question of rating for a boiler. The writer has always taken ten square feet of boiler heating surface for one boiler horse power. This is done for two reasons. First, it gives the approximate heating surface immediately by adding one cipher; and the heating surface is a reliable factor of size. Second, it has been found that for most boilers the best results are obtained with an evaporation of about 3.5 pounds of water from and at 212° F. per square foot of heating surface per hour, which corresponds very closely to 10 square feet of heating surface per boiler horse power.

The rating has nothing to do with developed horse power, as an evaporation of 10 pounds of water per square foot of heating surface per hour can be attained, which will result in about 3½ square feet of heating surface per boiler horse power. It is also possible to go to the other extreme and have excessive heating surface. This is sometimes advisable where considerations governing the installation make it advisable to combine the heating surface of a boiler and economizer in one unit, this unit performing the function of both.

It is customary to assume a uniform heat transmission for the entire exposed heating surface. Each square foot of heating surface is then capable of transmitting a certain amount of heat, depending on the conductivity of the material, the character of the surface, the temperature difference between the gases and the water, the location and arrangement of the tubes, the density of the air, the velocity of the gas, and the time allowed for transmission of the heat.

Noel Deerr (3) observed in this connection:

> I have always held that economy in combustion is obtained in the furnace and that the boiler plays a comparatively small part in fuel economy. Water tube boilers are, however, made in units of much larger dimensions than the return tubular boilers, hence for a given heating surface in the boiler there is less exposed radiating surface with the water tube boiler than with the return tubular boiler.

There are two other important considerations in the attainment of rating in a bagasse boiler—as compared with coal and oil-fired boilers—and these are lack of absorption by direct radiation to boiler from the combustion chamber and the lower gas temperatures. In this respect, the bagasse boiler is about in the same class as the wood waste fuel boiler and better off than the waste heat installation.

Steam, published by The Babcock & Wilcox Company, informs us as follows:

In direct-fired coal or oil-fired practice, where furnace temperature of from 2,400 to 2,800 degrees are commonly developed, the amount of heat absorbed by direct radiation from the furnace represents a very large percentage of the total heat absorbed by the boiler.

If the results of direct-fired boilers and waste-heat boilers are to be compared from the standpoint of total heat absorbed as measured by steam output, the increased absorption through radiation in the direct-fired boiler must be offset by a corresponding increase in absorption by convection in the waste-heat unit over that absorbed by convection in the direct-fired boiler. For high rates of convection absorption, high rates of heat transfer are essential, and such transfer rates necessitate high gas velocities.

For boilers developing approximate rating in the two classes of work, with waste gas temperature of from 1,200 to 1,300 degrees entering, and the arrangement of direct-fired boiler surface ordinarily found in stoker-fired work, the velocity of gas through the waste-heat unit is probably slightly more than three times that through the direct-fired boiler.

There are tests on record showing waste-heat boilers developing considerably over rating with temperatures of gas at 1700 to 2100° F., which is certainly no better than bagasse boiler work.

This would lead one to believe that the so-called high type of boiler, or one that is narrow for its particular H. P. rating, would lend itself to our conditions on account of the high velocity of gases. This would be so provided that the necessary grate area could be accommodated without too much expense or too much lost heat by increased radiating surface.

The following table is presented to show the differences that probably exist in bagasse-fired and coal-fired boilers:

TABLE 1

	Coal	Bagasse
B. T. U. per pound of dry fuel	12,825	8,350
B. T. U. per pound of fuel as burnt	12,248	5,010
B. T. U. lost in flue gases at 500° F.	2,408	1,635
B. T. U. available for useful work	9,840	3,375
Temperature of combustion	2,746	2,156
Cubic feet of flue gases 500° F.	459	198
Pounds bagasse equal to pound of coal	......	2.92
Cubic feet of flue gases from 2.92 pounds bagasse	......	578

This shows that it takes 2.92 pounds of bagasse to equal a pound of coal—the temperature of combustion is lower and the volume of gases is 39 per cent greater when considering the same available heat.

It is considered good practice to assume 5 pounds of coal per B. H. P. at 150 per cent rating; this gives us 3.33 pounds per B. H. P. This corresponds to 9.73 (3.33 x 2.92) pounds of bagasse per B. H. P. at rating. This figure of 9.73 checks very closely with actual experiments in Hawaii.

As far, then, as boilers themselves are concerned, there is no valid reason why rating, or more than rating, can not be attained, provided the necessary heat units are supplied to the boiler from the furnace.

Grates

The function of the grate is to furnish, with as little loss as possible, sufficient combustion to furnish the required hot gases to attain the boiler rating, previously decided upon, as desirable.

The amount of draft has quite an effect on the amount of bagasse that can be burnt per square foot of grate area per hour.

Oahu Sugar Company, Ltd., can get 125 to 150 rating out of their boilers with .077 square foot of grate per B. H. P., while at Ewa, we employ .215 square foot for the same results and the new boiler installations at Waimanalo have about .170.

It would seem reasonable to suppose that the amount of bagasse burnt per square foot of heating surface per hour in all three cases should be about the same. We can assume that one pound of bagasse is required per S. F. H. S. per hour.

This checks very closely with the figure derived in the previous computations, which is .975 pound per S. F. H. S. (or 9.75 pounds per B. H. P.).

The pounds of bagasse per square foot of grate surface per hour at 125 per cent boiler rating for the three installations mentioned are:

Oahu—163 Waimanalo—75 Ewa—58

The Honolulu Iron Works Company have been kind enough to furnish the following information on 14 Stirling boiler installations of their design. Assuming 100 per cent rating, and one pound of bagasse per square foot heating surface, the pounds of bagasse burnt per square foot of grate area per hour vary from 70 to 96, with an average of 81. Assuming arbitrary ratings from 90 to 120 of full rating load, we find:

Per cent rating	90	100	110	120
Pounds bagasse per S. F. G. A. per hour	73	81	89	99

Admitting that these are all assumptions, they are not very far off, as there is no logical reason why the amount of bagasse burnt per square foot of boiler heating surface per hour should vary greatly. If there is any great variation, it is an indication that the furnace design is faulty, provided the moisture in bagasse is fairly uniform.

The deduction then is, that for the amount of draft encountered on most plantations, the pounds of bagasse per square foot of grate area for Stirling boilers is about 75 pounds instead of 100 to 125 as usually understood.

It is interesting to note in this connection, that the Kennedy Patent Furnace increased the output of the boiler considerably above rating. This was an increase in rate area and furnace volume only, and neglecting the furnace would tend to indicate that increased grate surface alone was what was needed. Since the draft was not changed and the flues and stack were able to handle the increased volume of gases evolved, this would eliminate draft as the important factor and again stress the importance of grate area. The furnaces for these boilers were originally laid out after the Hawaiian practice, and following in our footsteps, failed to develop the rating desired. Assuming 1.2 pounds bagasse per S. F. H. S. per hour, we have the following pounds of bagasse per S. F. G. A.:

100% rating—58 125% rating—72.5 150% rating—87.5 175% rating—99.5

The effect of furnace changes was left out of our consideration as the changes did not alter the ratio of furnace volume to grate area to any appreciable extent.

It is hoped that there will be some discussion on this point of the desirable amount of bagasse to burn per square foot of grate area. Consideration of draft will be taken up later.

It is believed that, at least for Hawaiian conditions, the step grate has certain advantages over the so-called flat grate of Cuba. One of the very important factors for complete combustion with a minimum of excess air is to bring the combustible, whether in a solid or gaseous state, into intimate contact with the available oxygen in the air drawn into the furnace. It would appear then that the step grate, drawing a good part of the air for supporting combustion through the fuel bed of practically uniform thickness, would have a much better chance for combustion with a minimum of excess air than the furnace with a burning cone of bagasse, and introducing air on all sides of the cone through openings in the furnace, or around the edges of the cone.

The big lumber mills used to dump their wood refuse on flat grates, but are now building elaborate furnaces. They are having just as good results with the step grate as with flat grate construction. (See A. S. M. E. Journal, July, 1925.)

The tendency in the Philippines is to have very steep step grates (about 60° from the horizontal) and install 3- or 4-foot bottom grates. The moisture content of Cuban bagasse is in the neighborhood of 48 to 50 per cent and in the Philippines about 47 per cent. This may have an important bearing on type of grate needed.

Furnaces

The ideal furnace is that which will completely consume the combustible with the least surplus air. To obtain this result the furnace temperature should be the maximum that can be maintained, and combustion should be complete within the furnace. There is nothing new in this, as A. Gartley, in 1918, pointed out that "for efficient combustion it is essential that a high temperature be obtained in the furnace, that products of combustion have as high a per cent of CO_2 as possible, and that the stack temperature be low."

Complete combustion with the *least surplus* will give *maximum temperatures* and the nearest approach to the ideal possible. Each of these three main factors has such a bearing on the net result that we will discuss them separately, with respect to their bearing on furnace design.

The maximum temperature that can be maintained in any furnace under present approved furnace construction is about 2200° F. to 2400° F. when loaded to 20 pounds to the square inch. Reducing the allowable load to 10 pounds per square inch will increase the permissible temperature about 200° F. It is necessary to keep down the furnace temperature in coal- and oil-burning furnaces by placing the boiler directly over the burning fuel and letting the boiler absorb some of the heat of combustion by radiation.

With bagasse, this is not necessary. Therefore, any furnace that is so designed that there is no intervening wall between the fuel bed and the boiler is taking

chances, because, if there is a lowering of the temperature below the point where combustion is supported, losses will occur.

The temperature of combustion, for various moisture content of bagasse and variable amounts of excess air, is:

TEMPERATURES OF COMBUSTION

Excess	Per Cent Moisture of Bagasse						
Air	36	38	40	42	44	46	50
50%	2756	2731	2677	2621	2591	2527	2436
75%	2452	2433	2366	2340	2317	2263	2187
100%	2211	2196	2156	2116	2097	2050	1985
125%	2013	2007	1967	1931	1916	1875	1819

(Assuming 8350 B. T. U. per lb. dry bagasse and 80° F. Room Temp.)

Since 75 to 100 per cent excess air is not considered abnormal, it is evident that there is not much danger of overheating the furnace. It is also usually found that the actual furnace temperature is less than the computed, especially where heat is removed by radiation.

Mr. Kerr (5) took many furnace temperature readings and submitted the following in his general remarks:

Factory	Average Furnace Temperature	Average Rate of Combustion	Average Evap. per pound Dry Bagasse
A	1633	130	4.64
B	1511	90	4.10
C	1420	62	4.00

(Factory "A" had highest CO_2 readings.)

These figures are lower than the figures from the above table under 50 per cent moisture. (This is the approximate moisture of Cuba and Louisiana.)

Why there should be so much discrepancy is not known, unless heat is allowed to escape by radiation. One very important point is indicated, though, and that is the benefits of the higher temperatures.

Under a closed furnace and one that is known to be quite hot, there are conditions present that appear as if the fire brick was melted on the furnace surface. I am inclined to believe that this is a chemical action due to the iron and lime in the bagasse and not a temperature action. Calcium and iron are both violent fluxes to fireclay brick made of normal mixtures of oxides of aluminum and silicon. An analysis of furnace ash selected at random by the H. S. P. A. Experiment Station showed 6.43 per cent iron and 6.23 per cent lime.

G. F. Gebhardt states that the temperatures necessary to cause a union of oxygen and fuel are approximately as follows:

Carbon Monoxide—1211° F. Hydrogen—1100° F.

It is very important that the temperature of gases should not be lowered below the point of combustion of carbon monoxide until we are assured that this combustible has been consumed.

This leads us to the consideration of complete combustion. The large lumber companies of the Northwest, realizing the value of waste wood and hog fuel in salable electrical energy, have done extensive research work in furnace development.

Mr. Kerr (5) was not able to draw any conclusive deduction about furnace volumes in his report on account of other variations.

The only dangers then of too large a furnace are radiation and leakage losses.

There is an economical limit to the amount of excess air that should be admitted for combustion. Adding more air will so increase the volume of gases as to incur losses at the expense of complete combustion.

Practically every furnace of fairly large dimensions, designed for bagasse or wood waste fuel, has ports of auxiliary air inlets for the admission of air other than through the fuel bed. Jacobus (7) and Simeral (8) claim "that gases containing excess air will ordinarily mingle more readily with the hotter gases containing unconsumed combustible matter, if they are made to travel over and above the hotter gases within the furnace, as this leads to an eddying action, due to the greater density of the gases containing excess air."

It is interesting to note that this theory has not been put into practice, the engineers probably depending on the shape of the furnace to accomplish the mixing action.

For the nearest approach to the ideal furnace then, the main consideration is the shape of the furnace. It is not sufficient to be large enough. It is more important to have it long enough. This is necessary to allow time for mixing and time for complete combustion after mixing has taken place. The more complete the mixing, the more thorough the combustion, and the less excess air will be required for complete combustion.

The drop nose arch as shown in both wood-burning furnaces is gaining much favor in assisting in the mixing. I would like to see this principle tried out. If applied, this feature would have these advantages:

1. Protect the furnace from radiating heat to boiler and reflect high furnace temperature on fuel bed, producing quick evolution of volatile matter.
2. In conjunction with bridge wall, would impose a barrier to smooth flow of gases, the bridge wall below and the drop nose above, creating an eddying and mixing action aiding in complete combustion with minimum excess air.
3. The bridge wall and drop nose create an actual longer path for gas travel allowing time for complete combustion.
4. The deflecting of the gases down insuring that section "A" will act as part of combustion space.

It is not claimed that this is the only way to accomplish these results. There is room for improvement and some thought along these lines will bring results.

There is a mistaken idea sometimes that flue gas analysis is a measure of furnace efficiency. D. S. Jacobus (7) states as follows:

> The flue gas analyses are not all that govern the efficiency, as much depends on whether or not there is delayed combustion between the boiler tubes. It is all wrong to assume that if two boilers are operating with the same average flue gas analyses and per cent of carbon in the ash, the furnace efficiency is the same in each, as actually there may be a wide difference due to the fact that all of the combustible gases may be consumed in the furnace in one case and not in the other.

It is necessary, then, to properly design our furnaces and control them with CO_2 readings.

The important point is to note the direction of flow of the gases. I believe the following rule will cover furnace volume qualifications: Furnace volume shall exclude all volume back of apron arch at bagasse feeder and include all volume following the direction of flow of gases up to a point where gases leave the furnace, or extension thereof, and come in contact with, or approach, the boiler.

Chimneys

The height and diameter of a chimney depend on the amount of fuel to be burned, its nature, the design of the flue, with its arrangement relative to the boilers, and the altitude above sea level. The last consideration can be neglected as the chimneys here are not at any appreciable altitude.

The method best suited for determining the proper proportion of stack and flues is dependent upon the principle that, if the cross-sectional area of the stack is sufficiently large for the volume of gases to be handled, the intensity of the draft will depend directly upon the height; therefore, the method of procedure is as follows:

1. Select a stack of such height as will produce the draft required by the particular character of the fuel and the amount to be burned per square foot of grate area.
2. Determine the cross-sectional area necessary to handle the gases without undue frictional losses.

It is poor economy to restrict the size of the flue and thus make additional stack height necessary to overcome the added friction. The general practice is to make the flue as large or slightly larger than the stack. A good figure is 20 per cent larger than the stack, and a safe rule is to allow 52 square feet for every 1000 boiler horse power. (This corresponds to about 42 square feet for coal burning practice.)

There are so many variables entering into the figuring of chimney sizes, that empirical formulas, based on experience, have taken the place of theoretical computations. In our case, for instance, not as much draft is desired as in coal burning practice, as there is danger of carrying the fuel off the grate; and yet, for the same heat available for useful work 25 per cent greater volume of gases.

The Honolulu Iron Works recommend about 130 feet above grate for a chimney for bagasse without economizers. This gives us about 0.52 to 0.72 inches of draft developed. This checks fairly closely with replies to G. H. W. Barnhart for his paper on Comparative Data on Factory Equipment, the values ranging from 0.5 to 0.9 inches of water at damper.

At one plantation, in the Philippines, where a 130-foot stack was installed, it was found advisable to increase this by 40 extra feet of height. If we are agreed that 0.7 inch at damper is sufficient to properly burn bagasse, either one of two explanations is possible: the stack was too small in diameter or the grate area was not sufficient. This brings us back to the previous considerations of desirable grate area. Admitting that anyone can increase the rate of combustion by increasing the draft, would it not be better to increase the grate area? (The diameter of the stack would be the same in either case.)

The volume of gases evolved by burning bagasse is easily determined, and it is a simple matter to calculate the diameter, with a fair degree of accuracy, if the horse power developed is known.

The following table was computed from a table which may be found in most handbooks and the following assumptions have been made:

1. Allowance has been made for 125 boiler rating, or 1¼ pounds of bagasse per S. F. H. S. per hour.
2. Height of stack 130 feet above grate.
3. Temperature of flue gases, 500° F.
4. The bagasse moisture .40.
5. The excess air is 100 per cent.

DRAFT IN INCHES OF WATER

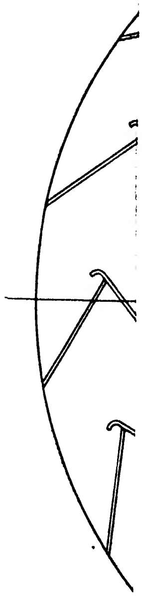
Boiler H. P. Allowing 150% Rating	Diameter of Stack in Feet								
	4	5	6	7	8	9	10	11	12
600	.55	.77	...	...	...	...	...	...	...
672	.44	.73	.82	...	...	...	...	...	...
768	.30	.68	.79	...	...	...	...	...	...
864	...	.64	.78	.83	...	...	...	...	...
960	...	.59	.75	.82	...	...	...	...	...
1152	...	.46	.70	.79	.83	...	...	...	...
1536	...	...	.56	.73	.81	.83	.85	...	...
1920	...	...	...	.65	.77	.81	.83	...	...
2400	...	...	...	.53	.70	.78	.82	...	...
2880	...	...	...	...	.62	.73	.79	.82	.83
3360	...	...	...	...	.52	.68	.75	.81	.83
3840	...	...	...	...	...	.62	.70	.78	.81
4320	...	...	...	...	...	.56	.69	.75	.79
4800	...	...	...	...	...	...	.64	.73	.78

For	350° F	deduct	.16
"	400° F	"	.10
"	450° F	"	.05
"	550° F	Add	.05
"	600° F	"	.09
"	650° F	"	.12
"	700° F	"	.16
"	750° F	"	.19

The following table shows the effect on chimney of varying the bagasse moisture and excess air. The factor given is to be multiplied into the boiler horse power rating in the previous table for corrected rating:

FACTOR FOR HORSE POWER RATING IN TABLE OF AVAILABLE DRAFT FOR 130-FOOT STACK FOR VARYING MOISTURE CONTENT AND EXCESS AIR

Excess Air	Moisture Content					
	36	38	40	42	44	46
50%	1.38	1.36	1.33	1.31	1.28	1.24
75%	1.19	1.17	1.15	1.12	1.10	1.07
100%	1.04	1.02	1.00	.98	.96	.94
125%	.83	.82	.80	.79	.77	.75



REPRESENTATIVE BOILER INSTALLATIONS

1	2	3	4	5	6	7	8	9
Boiler No.		Type of Boiler	Boiler Horse Power Rating HP	Square Feet of Grate Area GA	Cubic Feet of Furnace Volume FV	Grate Area Factor GAx100 / HP	Furnace Volume Factor FVx100 / HP	Combustion Time in Seconds
1.	Hawaii—older setting	Ret. Tub.	254	41	199	16.1	78	1.13
2.		B. & W.	396	85	480	21.5	121	1.16
3.		Stirling	411	44	218	10.7	53	1.11
4.		Stirling	493	38	420	7.7	85	2.48
5.		Stirling	603	54	590	8.9	98	2.46
6.	Hawaii—newer setting	B. & W.	396	64	674	16.2	170	2.36
7.		Stirling	545	101	1161	18.5	213	2.58
8.		Stirling	391	66.5	820	17.0	210	2.90
9.	Philippine (Kennedy)	Stirling	630	130	1045	20.6	166	1.80
10.	Cuba	Ret. Tub.	254	(41)	1094	16.1	430	6.00
11.		Stirling	603	(58)	973	9.6	161	3.76

The factor 100 used in computing columns 7 and 8 is used for simplicity only.

The last column shows the time in seconds for a complete change of volume of gases in the furnace and is added to indicate the rapidity with which combustion is taking place. It is figured at 81 pounds of bagasse per square foot of grate area, and in some cases it is known that this figure is greatly exceeded.

C. H. Courser, in *Power*, of November 20, 1923, has the following to say, which might be of interest to some of the engineers:

FLUE GAS THERMOMETER AS SUBSTITUTE FOR CO_2 INSTRUMENT

It is probably the wish of most engineers to have a recording CO_2 instrument, with which to check boiler performance, but sometimes the cost makes it hard to get the approval of the powers that be.

We have been trying out recording flue gas thermometers and find that results in small plants compare quite favorably with CO_2 instruments. We know that with a clean boiler, good baffles and settings, and with 13 or less per cent CO_2, the excess air is cut to a minimum and the temperature of the flue gas will be low; that is, from 100 to 200° F. above the temperature of the water in the boiler, depending on the load. The temperature of the water in the boiler can be found from the steam tables. At normal rating there should not be over 150° difference. If we admit an excess of air, the flue gas temperature will immediately rise, and the more the excess, the higher it will go.

With a long distance recording thermometer installed at about one-third the cost of a CO_2 instrument, we have a fairly good check on the condition of the boilers and how the firemen handle the fires. If the temperature goes up, there is probably one of three things the matter: an excess of air, dirty tubes, or leaky baffles. The CO_2 instrument might show good CO_2 and still the tubes could be dirty or the boilers have leaky baffles. Of course, for best results, the instrument should be placed where the firemen can see it at all times. We use the recording thermometer on both oil and coal fired boilers and get equally good results.

Boiling House

Wm. Kruse, of Kekaha, reports:

The Western States Machine Company Robert Gibson self-discharging centrifugals with all latest labor equipment are working very satisfactorily. The four machines dry

700 cubic feet massecuite in 1 hour and 10 minutes. It took the American flat bottom machines, built in 1922, from 2 to 2½ hours to do the same work, with moisture in the sugar about the same.

We have run the new machines 925 r. p. m. and expect to increase speed to 1,000 r. p. m. during 1925 repair season. We are fully convinced that these machines will dry from 200 to 225 tons sugar in 24 hours without ever working the four machine men, which would make 50 tons per man in 24 hours.

Arthur F. Ewart and Seymour Terry have made improvements in entrainment traps for which they seek patent protection.

This trap is placed in the upper part of an evaporator or vacuum pan cell in which the evaporation or vapor production takes place.

To trap particles of liquor that are projected up from the boiling mass and are carried along with the vapors, numerous devices are employed.

With the employment of this device two important requirements of an entrainment trap are fulfilled: (1) The complete impingement of entrained particles of liquor, that move at considerable speed along with vapors. (2) The collecting of the impinged and precipitated particles of liquor and conducting them away from the path of the moving vapors back to their source.

The novelty of this design lies in the zigzag shape of the baffle vanes and the arrangement of plates and channels for centrally collecting and returning the trapped liquor.

Water Cooled Crystallizers

An improvement which has been worked out by Messrs. Ernest W. Kopke, William Wyllie, and H. S. Walker in the Philippines, is a crystallizer cooler for low grade massecuites. This consists of a set of cooling coils spaced across the crystallizer in such a way that each coil takes care of a definite volume of massecuite and does not interfere with the motion of the stirring arms. The original stirring arms are utilized, the cross pieces only being removed. Massecuites have been cooled from 160° to 100° F. in 36 hours, with cooling water at 86° F., without the formation of any false grain. This is particularly advantageous where it is desirable to carry a small stock in process, since one water cooled crystallizer will do the work of more than two air cooled crystallizers, and the cooling equipment, including royalties, can be put in for less than half the cost of a new crystallizer. The idea of water cooling, of course, is not new, but the arrangement of stationary coils has a great many advantages which we in Hawaii might try out.

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Camp Improvements*

By Donald S. Bowman

The improvement of morale and health is largely conditioned by camp improvements. This is now fully realized by plantation owners and managers. There can be no other deduction when one is familiar with the rapid progress being made in rehabilitation and new construction work on the sugar plantations throughout the Islands.

For several years past, the average expenditures for construction and maintenance of camp dwellings have been over $1,400,000 per year, while the amount expended for medical service and sanitation has been about $640,000 per year. Aside from these sums, large amounts have been invested in roads, domestic water supplies, etc., all of which have their effect on morale and sanitation.

First Sugar Camps

The first sugar plantation was started in Manoa Valley in 1825. This, however, failed, and the next attempt was made at Koloa, Kauai, in 1835. This plantation has been operated continuously since then. In 1835, aside from a small camp near the Koloa Mill, the laborers, native Hawaiians, were housed in their own villages.

It is most interesting for one concerned with housing problems and camp improvements to study the housing of the primitive peoples of the world, and to note that it is evident that the Hawaiians at the time of Vancouver and other early voyagers, were better housed and more domesticated than any of the other aboriginal peoples. From a description of their housing, obtained from articles written in Vancouver's time and later, we learn that they were not only well and completely housed, but that their villages were arranged according to a comprehensive plan that corresponds today with what we know as city or village planning.

The principal houses were located in close proximity to the heiaus in the larger permanent villages. Separate dwellings housed the chiefs, the kahunas, the retainers, the women, and the men. The dwellings of these early Hawaiians varied according to the rank and means of the owner, the houses of the field laborers or fishermen being huts 8 x 10 feet to houses 12 x 20 feet, while the houses of the chiefs varied from 40 to 70 feet in length. Except in the case of a chief, each man built his own house. When a chief wanted a house, all those who held land under him built it. The houses were well built and thatched and would last from five to ten years. They were simply furnished with lauhala mats, baskets, gourds, calabashes, wooden dishes, tapas, etc.

* **Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.**

Evidence of their knowledge of good sanitary practice was found in the disposal of their refuse, in the segregation of the sick, in the use of the spitoon, etc. They evidently led a sanitary, simple, and contented life.

We find that they did not take kindly to plantation work and that only a small percentage could be induced to work in the fields. This necessitated the importation of labor, and in 1852 the first Chinese were imported. From that date, the plantation camps were started. In 1868, the first Japanese laborers arrived, followed in 1877 by Portuguese, in 1881 by Norwegians and Germans, later by Russians and Spaniards, and finally, Filipinos. The changes in nationalities and the recruiting of families in place of single men have resulted in changes in housing. It seems better practice to build family houses rather than those designed for single men, as the family houses can be converted into dwellings for single men with minor changes. The H. S. P. A. convertible type of house has met with much favor. Although two-family houses for the smaller families are still in vogue, it is generally conceded now that the one-family type of house with separate sanitary facilities is the ideal.

Sanitation Important

With the passing of the barracks type of dwelling, which housed large groups of both single and married men, the improvement of camps has been of steady progress. Solutions of housing and sanitary problems have been arrived at only after a careful study of the requirements and through the cooperation of all interested parties.

The greatest improvements made during recent years and the most noticeable are in camp sanitation. The community privy, indecent and unsanitary, is obsolescent; its place has been taken by sanitary facilities designed for the use of one family or small groups of single men. Improvements in facilities led to a study of the disposal of waste water and fecal matter. With the hearty cooperation of the different plantations, a lengthy study and a number of experiments were conducted. As a result, the H. S. P. A. method of sewerage disposal and sanitary outbuildings was developed. This method has been adopted as the standard by most plantations.

Plan Your Camps

The general rule adopted before camp improvements are undertaken is to map out and place on paper the proposed new work, the map showing streets, lots, sewers, water supply, location of houses and sanitary outhouses, sewerage disposal, etc. These plans are then approved by the plantation manager and other interested parties. Building plans to suit the various requirements and local conditions are supplied by the H. S. P. A. These plans are carefully checked to insure their compliance with the various laws, rules, and regulations respecting housing and sanitation. Utility, comfort, and sanitation are the principal considerations.

The cost of housing and sanitation must receive careful consideration. The cost is based on the general type of construction and is usually figured at so much per square foot of floor space. Houses containing 480 square feet of floor space, including four rooms, two of which are bedrooms, have been found to fill

the general requirements. All sanitary facilities, with the exception of the kitchen sink, are placed in a separate sanitary outbuilding connected with the H. S. P. A. type of sewer.

While many splendid improvements have been accomplished, there is much to be done before all of our plantation villages can be classed as meeting present-day standards. The camp improvements completed during the past five years show a remarkable progress and prove the keen interest that is being manifested by the owners and employers of the plantations. Better types of houses, with adequate sanitary facilities and more healthful surroundings, are the rule.

We recognize that contentment with the housing and surroundings certainly has its effect on a man's producing power, and that good health influenced by sanitary and healthful surroundings plays an important part in keeping up the production by an increased turn-out and a decreased labor turn-over.

Cane Fires*

By J. S. B. Pratt, Jr.

Cane fires have such a destructive effect, with loss of investment, water, fertilizer, labor, and growing time, that the suggestion has been made that we discuss at our Sugar Technologists meeting ways of fighting and preventing fires.

Fires may be *accidental, incendiary,* or *intentional.* On a sugar cane plantation, we may have grass, trash, young cane, mature cane, building, and forest fires. In this paper, we will concern ourselves mainly with mature cane fires, but, in passing, it will be well to mention good ways to stop grass and trash fires.

Grass and Trash Fires

The best aids in fighting grass fires are shovels of earth, trenches to prevent creeping, green branches, wet bags, and hoes. Grass fires give so much smoke that it is hard to work on the lee side. It is easier to work with the wind on two sides, pinching it to a narrow point. With large grass fires, time will be saved by using a plow and turning a few furrows. Trash fires are similar to grass fires, and in both, buckets of water thrown in a fine spray are very effective in checking the fire at critical points. When using bags, branches, or in throwing earth, be careful not to fan the flames. A large number of our cane fires are started from grass or trash fires, very often, because we get careless and burn without regard to wind or to dryness.

Intentional Fires

In Hawaii, we have for a number of years burned off our cane before cutting. There is not only the labor saving in harvesting of very often as much as 40 per cent, but there is the labor saved in starting off the ratoons. J. A. Verret writes:

Burning off before cutting the cane was becoming the general practice about the years 1909 and 1910. Its general adoption was brought about mainly on account of labor shortage and lessened cost of harvesting. The first mention of burning before cutting made in the

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H. S. P. A. annual committee reports, as far as I have been able to find, was by W. W. Goodale in 1909. In 1910, L. Weinzheimer reported on this practice as then carried on at Pioneer Mill. Among the first places where burning was done was in the Lawai Section of McBryde in 1902. Kahuku, as far as I know, was the first place on Oahu. In the beginning, the practice was done not so much as a labor saver as on account of borers. I understand that burning off before cutting is a general practice in South Africa, where Uba is the standard cane. I know of no other country where burning off is practiced as a general thing.

Burning off destroys rats, diseased cane and injurious insects, and, of course, our friendly insects.

Experience is our best guide to burning off. One learns when to take the fire fast, when to go slowly, how to create a draft to make the sparks go up, when to have plenty of men at a fire, when not to burn, and so forth. At Pioneer, for instance, burning off early in the morning with only a few men at hand is customary. That is their job, to burn off, and to cut the firebreaks for the next day's burn. They become expert at it and use a very narrow firebreak with a small stream of water, taking advantage of an early morning breeze to make it safe. To one not used to burning off in this way, it seems dangerous. These men, however, are trained, are alert, and are active when a spark jumps. Men should be trained to be careful and not to be afraid. It pays to pick men for fires, and the more men are trained in this way, the more fortunate is the plantation when accidental fires occur. They gain confidence and are not afraid when trouble comes. Men of this type are worth sevenfold the untrained men, and with the untrained man, there is more danger of loss of life in our accidental fires.

Accidental Fires and Incendiary Fires

These happen on the best organized plantations. Someone careless in smoking, a strong unexpected wind carrying a spark far from some burn, dry grass or trash, a locomotive spark, a nitrate bag left carelessly by cane, or even some firebug, disgruntled laborer, or strike agitator will start a cane fire.

Let us follow a cane fire through, telling what we would do and what we would *not* do. Experience is our best teacher for fighting fires, and some of us here may have certain experiences to tell our fellow members that may be helpful.

It is night, and Manuel, riding home from a visit to his old father, sees a glare in a nearby field. There can be no mistake in what it is. Fire! Some careless fisherman returning from the beach, drops a cigarette in the grass by the road that should have been cleaned, and the cane stripped back a line or two. But the fire has just started, and Manuel gallops on, knowing that the first thing he must do is to find if it is something he can put out quickly. Or possibly a few men in Camp 5 right nearby can put it out before it gets headway. At the start a few men can very often put a fire out, and if time is lost in going for more help the fire gains headway. Very often general alarms are given and, like the fable story of "wolf-wolf," men hold back after coming to a few false alarms. And a few men at the start taken quickly to the scene of the fire are better than arousing the whole plantation, losing time in so doing, and having poor turn-outs the next day.

But Manuel, on getting closer, finds that the fire is larger than it looked at first, and he must ride fast to give the alarm. He gets the night watchman at the

mill, or the nearest telephone to let the "higher ups" know. Someone in authority should be on the plantation at all times, for we have other people's money tied up in our fields and property.

The fire being a bad one, the general fire whistle at the mill is blown. I have seen many fires that did not require a lot of men. Small blazes are very deceptive at night. The general alarm should be given only when those in authority investigate and find it necessary. Minor fires may require only a truckful of men, but, of course, I would not hesitate if conditions warrant in arousing the whole plantation.

Steam is kept on one locomotive at all times that laborers may get to the fire, and that the alarm may be blown in case the mill is not running. The warehouse men rush to the warehouse to get the knives, hoes, shovels and buckets. The reservoir men and ditchmen already have standing instructions to get water in the nearest ditch, for in the excitement someone may forget this first requisite. These men know the ditches that carry the water in the shortest route, and they must be trained to think of water first.

Manuel, we leave with the other lunas in getting the men to the fire in trucks, autos, locomotive, on horseback, and on foot. The truck drivers know they must go to the camps to get the men who are already being aroused by the camp boss, and they must get their loads as quickly as possible, get to the fire, and then go back for more men. Their trucks are fully equipped with cane knives, as are all the locomotives, for a man must have some tool at a fire.

Fortunately, our fire has not gained much headway. The head overseer on reaching the fire sizes up the situation, where the firebreaks are to be, etc. Here the tendency is to get too close to the fire, making it impossible to do anything on account of the smoke, and making it more dangerous for the men. Also the backfire will then have no time to work back before the fire is upon it, and we have the whole thing to do over again. The fire jumps sometimes 300 feet, depending on the variety of cane, the wind, or the dryness of the field. May we digress here to the topic of *firebreaks.*

In choosing firebreaks, we must study the wind, its velocity and direction, the terrain, ditches, ridges, and roadways. A fire can be stopped on a ridge easier than in a hollow where the cane is heavier. It can be stopped in cane at the beginning of a season when the tops of the cane are green and there are no dry leaves to cause a jump. A small leaf like H 109 is better than a broad leaf like Yellow Caledonia. A recumbent cane is better than erect cane. A night fire is easier to watch for these flying leaves than a day fire. In studying the wind, one may find a way to almost change the wind around, by creating a draft from a backfire made in a certain direction. The flames may be made to go up as they would in a chimney. So it is important to pick the right firebreaks. Very often it may be best to start two firebreaks, working with the wind and pinching the fire. In this way, the men are in less danger and they are in fresh air, so that they can be called when the critical time comes, and not be exhausted. And repeating, do not cut the firebreak too close to the fire. Take plenty of room.

Having chosen our firebreak, the first essential is that the men know what to do. Here is where the lunas come in. One often sees a luna trying to put the whole fire out himself, having twenty of his men standing by, topping cane here and there, and not being directed. Men must be stationed to direct the others

coming to the fire. Pick out the old men, the ones that are not so useful in the fire, to stay by the main road, the ditches, etc., to show the stragglers where they are to go, or where they are to get knives. These precautions avoid confusion. Much needless expenditure of energy occurs where there is no directing head in charge, or where different plans are being followed. Someone starts a backfire and then the work must be done all over again.

Backfires are very necessary at times, but they may be dangerous and men may be trapped. And backfires often jump. Gangs working on both sides of the fire, out of the smoke, and pinching the fire to some ridge or corner of the field, can very often stop a fire without the danger of using backfires. The first essential in fighting a fire is to think of *life,* and one should not send men into a fire where one would not go himself, or where there is too much of a chance.

To go back to our fire. Our men know where to go and what to do. Our control means are firebreaks, backfires judiciously used, water, roads, ditches, green cane tops, shovels of earth, wet bags, and fire extinguishers. Green cane tops we place on the flames, keeping the flames down so that we may work the fire to a smaller head. In this connection, there is nothing more effective than buckets of water, and here training helps. A man who has never thrown a bucket of water, throws it in one place. Properly, it should be thrown in a fine spray in a motion similarly used by fishermen in throwing a throw-net. The finer the spray, the more effective it seems, for the water covers a wider area, and those of us who have burned off know that a small sprinkle of rain will often put a fire out that had been going very well. This year, I have carried a half-dozen buckets in the back of my car, and on several occasions they have materially stopped cane fires. I also have cane knives there. And each harvesting field is equipped with a box containing chains, links, double-trees for the hauling, and cane knives, buckets and shovels for emergency use.

One never knows how a man will act in a fire. Some are nervous and make others nervous. I would rather have a gang of a few trained confident men on a fire than too many men that do not know what to do and get in each others' way. Cane cutters who burn daily are the best at fires, but they will hang back unless proper leadership is shown. Even the directing head should occasionally jump in and spur the men on. But the leaders should prevent the men from crowding and thereby prevent accidents.

By hard work, then, our fire is out. We must be careful, right up to the end, for many a fire jumps at the last stretch when the fires from the two sides rush together. Or possibly we thought we had it out and had gotten too confident and had allowed a tiny flame to creep in some trash in the firebreak. We must leave men back to see that no spark fans up or stump smoulders. At night, when the flames are out, we are glad that we had our flashlights with us, so that we can see that all the men get out. The timekeepers then see that the men have time allowed for their work at the fires, and we go home exhausted, but with more experience on cane fires, particularly in learing what *not* to do.

Deterioration

Having had our cane fire, the questions always come up as to what we are going to lose; should we leave the cane standing or cut it all down as fast as we can; and after how many days will it be fit for the mill, etc.?

There are two reasons why I like to cut the cane down fast. One is that the men are keyed up to the fact that the plantation has had a fire and they will work harder. Next is that unless there is plenty of cane cut ahead, the track men cannot work, the loaders cannot load, the hauling is tied up and we do not get the cane into the mill at the greatest possible speed. Perhaps in wet weather it is better not to cut too far ahead for we must remember that we have two ends on a cut stalk for fermentation to work, though inversion starts quickly from the top of the stalk anyway.

Quoting from J. A. Verret, who has collected deterioration figures from all the Islands:

> In regard to burning, the best figures we have are from the Ewa tests, on mature cane, in hot, dry weather, which figures are closely corroborated by many others on all the Islands.
>
> The losses averaged about 3 per cent a day, or, say 15 per cent in five days. The loss on the first day is not so high. One thing to remember in this connection is that this loss consists not only in the deterioration of the juice but also in loss of weight in cane. As your cane gets older, you are having losses even when your juices show no change. Our tests show that there is no advantage to allow burned cane to stand rather than to cut it.

With regular burning daily, we should have no old cane. At McBryde, we make small burns, and figures kept on a year's harvesting show that 14 per cent of the cane reaches the mill within 12 hours from burning, 39 per cent is 24 hours old, 36 per cent is 48 hours old, and 10.5 per cent is 72 hours old, or a total of 99.5 per cent reaches the mill within 72 hours. The remainder, or one-half of one per cent, comes in within 96 hours and is cane sometimes held over Sunday, or because labor turn-outs were poor, or because the burn was misjudged as to tonnage.

Precautions or Prevention

1. Our men should know what to do and where to go.

2. They should be trained in fire fighting, and there is no better way than to instruct them daily when burning off, that they may thereby gain confidence.

3. The field layouts should be studied and corrected, that we have no large fields of cane of the same age adjoining. We thereby lessen our fire hazard and possibly distribute our water better. Incidentally, we intensify our culture.

4. Have plenty of field roads and ditches. They should be laid out as firebreak aids. Water is the main requisite for most plantations. The land given up to roadways is not lost, for we have better aids to supervision and to the cutting of firelines in regular harvesting and emergency, especially where we have heavy cane and firebreak cutting is slow.

5. Have all roadways stripped of trash, grass or fire hazards.

6. Have a general understanding for truck drivers, ditchmen, lunas, etc., as to what they are to do.

7. Have tools handy, especially knives and buckets.

8. Fire extinguishers. Several places have a battery of fire extinguishers for fire fighting. Their value comes in keeping the flames down in critical places. They must be tested and kept filled regularly, for often some laborer turns one over and then, of course, it is of no further use. Take one out to a regular burn-off and show the lunas how it is to be used. The locomotives should carry them;

so should the trucks. Hawi Plantation has a truck especially equipped with knives, extinguishers, chemical tank, buckets, and other fire apparatus.

9. The overhead system of irrigation lends itself to easy burning and to control of fires.

10. One good rule to try to follow is to burn off early in the morning, before the sun has a chance to dry the light dew off the leaves. The leaves will then be less apt to carry jump fires. Some plantations get night showers, making morning fires difficult, but it is well to remember that a day fire must be watched. The winds vary more in the day, when the sun is up, and we may then not have our regular night mountain or sea breeze.

11. In daily burning off, caution the men to be quiet, so that if the fire jumps, a warning can be heard. Keep the men out of the smoke as much as possible, so that they are fresh in an emergency.

12. Beware of trash and grass fires, for many a gust of wind or creeping has started a cane fire.

13. Have the locomotive stacks inspected regularly; even oil burners start cane fires, possibly from some leaky pipe.

14. Cut the firebreaks to run as much as possible in the same direction as the wind.

Summary

We may control cane fires much more effectively if our men are trained, if they know what to do, and have confidence. They must have means for fighting fire, such as water, tools and transportation. There must be a directing head, otherwise there is much needless energy expended. The better we are organized for fire emergencies, the more chance we have of preventing loss and lessening accidents.

Questions For Discussion

1. Has anyone an organized system for fighting and preventing fires?
2. Has anyone interesting experience to relate on a fire?
3. What is the worst cane fire remembered? How many acres, tonnage, cause, days before finished, etc.?
4. Has anyone found a fire extinguisher of value in a cane fire?
5. Has anyone figures on the average number of men required daily in cutting firebreaks? How are they cut, by allotment or by regular firebreak men? Is trash piled on windward or lee side. How about cane?
6. After a bad fire, how long has the cane been in good weather before the last stick was ground?
7. Am I right that a backfire should never be started until necessary?

The Factory Problem of Clarification*

By Walter E. Smith

Clarification of cane juice is seen on analysis to consist of four main physical or chemical reactions:

1. Flocculation of colloids by change of hydrogen ion concentration.
2. Flocculation of those colloids which are coagulated by heat.
3. Formation of insoluble lime salts.
4. Formation of soluble lime salts and chemical reaction products.

The production of a clear resulting juice is apparently the combined result of flocculation by change of reaction and heat, and the formation of insoluble lime salts. Simple change of reaction, together with heating, will not of itself result in the clear, sparkling clarified juice which is met in practice, because apparently certain colloids are not precipitated under these conditions; much of the suspended matter remaining in colloidal dispersion is carried down, however, by occlusion within the flocculent and voluminous precipitate of calcium phosphate produced by the reaction of the lime with the phosphoric acid of the cane juice. Thus the two phases of the reaction supplement one another and combine to produce juice of varying clarity, depending apparently on the over-all efficiency of the two factors in the reaction—the efficiency with which the colloids are coagulated by heat and alkalinity alone, and the production of the calcium phosphate precipitate. This theory of clarification offers a fitting explanation of our practical observations: that for a given phosphoric acid content, the clarity of the juice reaches its maximum slightly beyond the neutral point of phenolphthalein in the cold limed juice, thus establishing that as the optimum point when clarity of juice is used as the basis for comparison; that for a given reaction the clarity of the juice increases with increase in phosphoric acid, although not necessarily in this proportion after we reach an amount sufficient to meet the requirements; and last, that juice deficient in phosphoric acid will not yield bright, clear juice even if the reaction is at the maximum permitted by other working considerations.

The formation of soluble lime salts and chemical reaction products may be considered as an incidental phase of the question, introducing other factors which may set a limit on the extent to which we may carry liming; of this more will be said later.

For purposes of continuous operation, general practice favors heating juice practically to the boiling point or slightly beyond; this seems to give best flocculation and reduces the volume of settlings to the minimum for the existing conditions. With this factor set approximately at the boiling point, the only remaining factor within our control is that of the reaction at which clarification is conducted.

The ideal reaction is that which would give us:

1. Maximum elimination of non-sugars.
2. Minimum liability to loss by inversion.
3. Most complete flocculation of colloids, and most rapid settling.
4. Greatest clarity of resulting juice.

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

Of these, the first two are of paramount importance, affecting as they do the final recovery; the third, while actually a limiting factor in many cases, should really be subordinated to the main issues and may ordinarily be adjusted by the installation of sufficient *suitable* equipment properly operated. Clarity of juice is desirable as this becomes one of the major factors in determining the filtering qualities of the sugar produced.

Clarification investigations conducted at the Experiment Station have shown that in general the maximum increase in purity between mixed juice and clarified juice is obtained at a reaction of 8.0-8.3 pH in the hot limed juice Further examination of this reaction from the standpoint of the ideal set out above shows it to meet fully the second and fourth requirements.

At an original reaction of 8.0-8.3 pH, the clarified juice will not fall below 7.5 pH and at this, hydrogen ion concentration inversion will proceed so slowly, even in juices heated to the boiling point, that under practical working conditions losses may well be considered negligible. Further, at this reaction the clarity of the resulting juice reaches a practical maximum.

The advantages which accrue when clarification is carried at a reaction of 8.0-8.3 pH in the heated juice are so specific, under Hawaiian conditions, as to warrant proceeding on the basis that this shall be the ideal at which we aim, and any attendant disadvantages must be considered simply as difficulties to be overcome. *To maintain clarification at this optimum reaction, meanwhile operating at normal grinding rate and at full efficiency from the conventional standards of boiling house practice, may then be considered "the factory problem of clarification."*

Liming

The problem of actually maintaining the desired reaction uniformly and regularly is one of fundamental importance; by this is meant liming *all* the juice to the same hydrogen ion concentration, so that every portion of juice leaving the receiving tank below the scales is at the desired reaction. It is not sufficient to maintain the reaction of the clarified juice at a point corresponding to the desired hydrogen ion concentration for the heated juice; great variations between parts of individual scale tanks might exist at the time of heating, but a satisfactory average could still obtain after mixing in the settling tanks. With an average reaction of clarified juice corresponding to 8.0-8.3 pH in the heated juice, if irregularities exist in the original liming it must mean that some of the juice was considerably alkaline to phenolphthalein. In this portion of the juice it is certain that there would be abnormal destruction of glucose, and the cush-cush present would likewise be subjected to more than normally vigorous digestion with attendant disadvantages through solution of non-sugars. Whether or not other reactions taking place are reversible we are not in a position to say, though the two mentioned undoubtedly are not; however, observations by W. L. McCleery during factory inspections show a distinct improvement in the relation between turbidity, as measured by the Kopke turbidimeter, and phosphoric acid in the juice, when the liming was made uniform. The exact effect of irregular liming is perhaps difficult to demonstrate, but one of the most important reasons for absolute uniformity of liming is that without it we have no efficient basis for control. To base control of liming on the reaction of the clarified juice is funda-

mentally wrong, since it does not follow that any relation exists between the lime requirements of any particular quantity of juice entering process and of juice which preceded it by two hours; acidity of juice being discharged from the settling tanks obviously cannot be corrected by increasing the reaction of the juice then entering the heaters.

The most serious irregularities of liming appear to exist where there is only one receiving tank below the scale, in which the lime mixing is done while juice is being constantly pumped out, and to which quite over-limed press juice is being returned. As this receiving tank empties, just prior to the discharge of a new scale of juice, the alkalinity of the limed juice may be very high due to the large percentage of press juice. As the scale is discharged the lime measuring tank is emptied simultaneously and usually the entire amount of lime has been added while probably less than 10 per cent of the juice has been discharged from the scale. Thus the first portion of juice pumped to the heaters is distinctly over-limed, gradually decreasing in alkalinity until the scale is completely emptied, when the alkalinity again begins to increase toward the peak reaction. With the constant change in alkalinity of the limed juice it is seen that at only one brief period is the reaction equal to the average, and as a result it is practically impossible to estimate the actual lime requirements by tests of the cold limed or heated juice proper. The only indication is the reaction of the clarified juice at the time of drawing off, and this, of course, is quite inadequate for purposes of control.

This condition, however, can be easily remedied without recourse to the installation of extra tanks or changed liming systems. By a little experimentation the opening in the bottom of the lime measuring tank can be so regulated that practically the same length of time is required for emptying as for the discharge of the scale; if the lime is mixed with the juice immediately below the scale discharge valve, a rather thorough mixing will result, though it is well to supplement this mixing with agitation by compressed air. With such an arrangement the writer has succeeded in regulating liming so that the uniformity of reaction left little to be desired. Where press juice is returned to the mixed juice this is very satisfactorily handled by installing a receiver of small diameter (10-12″) and extending in height to the upper level of the receiving tank in the line to the raw juice pump. If the press juice is pumped to this receiver it will mix with the limed juice at a uniform rate and will be equally distributed, thus avoiding irregularities of reaction.

An arrangement having two mixing tanks with one scale, or three mixing tanks for two scales, gives a more flexible and more positive arrangement for the control of liming. Here the lime is added to a fixed quantity of juice, mixing is completed and the reaction tested before the juice is pumped to the heaters. Once the alkalinity is adjusted the entire contents of the tank may be depended on to be the same; press juice may be disposed of in the same way as previously described.

One further system is the use of continuous liming devices such as the Fleener arrangement, or that used in connection with the Petree-Dorr process. Theoretically, continuous liming should make possible an absolute uniformity of reaction, combined with a very positive control; the writer is inclined to believe,

however, that more serious irregularity is likely to be encountered with continuous devices than with a proper intermittent arrangement. With intelligent supervision the continuous installations work entirely satisfactorily, but in the smaller factories, where operation is likely to depend on unskilled laborers for considerable periods, intermittent liming seems less likely to result in operating difficuties occasioned by serious over- or under-liming.

No real reasons exist, however, for the marked irregularities in the reaction of individual parts of the same tankful of juice as found in many factories and by only minor changes the system can be adjusted to give satisfactory uniformity of liming. This is the very crux of the entire situation—the ability to maintain the reaction at just the right point with certainty—and no effort should be spared to achieve this end.

Heating

Juice heating presents no problem of special difficulty; with sufficient heating surface and a suitable steam pressure, the juice temperature should be readily controlled. Difficulties may usually be traced to one of four sources: Improper discharge of condensate, incomplete venting of non-condensible gases, improper cleaning, or throttling between the exhaust mains and the steamer chest of the heater. The proper functioning of traps is a mechanical detail that may be readily adjusted. Equal care should be given to the proper venting of incondensible gases, especially where heating is done with vapor from a pre-evaporator; where vapor heating is practiced provision should be made to prevent air being drawn into the steam chamber of the heaters in the event that the vapor pressure falls below atmosphere; this is readily accomplished by the use of check valves on the vent lines. At one factory the work of the heaters was greatly improved by venting the incondensible gases under vacuum. In this case the vents were connected to the third effect, rendering the work of the heaters automatic and regular, the temperature of the juice varying with the pressure of the steam applied at the calandrias of the pre-evaporator cells.

If the juice is heated to or beyond the boiling point it should be given opportunity to flash before entering the settling tanks; this seems to break up the foam and scum which otherwise would float on the surface of the juice in the settlers. A number of factories are equipped with a so-called pre-settler which acts as a combination flash tank and supply tank. Probably one of its principal functions is to act as a scum separator; on flashing into this pre-settler, such foam as is produced will rise to the top, and since the juice is drawn off from the bottom no floating scum will be carried over. When this scum breaks up and sinks of its own accord, it is in a state in which it will likewise sink in the settling tanks. Without such an arrangement considerable difficulty with foam is likely to be encountered.

Settling and Decantation

Maintaining clarification at the optimum reaction of 8.0-8.3 pH brings with it the specific problem of an increased volume of settlings. Laboratory tests and actual observations under operating conditions have well demonstrated that the volume of settlings increases progressively with the hydrogen ion concentration of the juice, reaching its maximum in most cases at a point somewhat alkaline

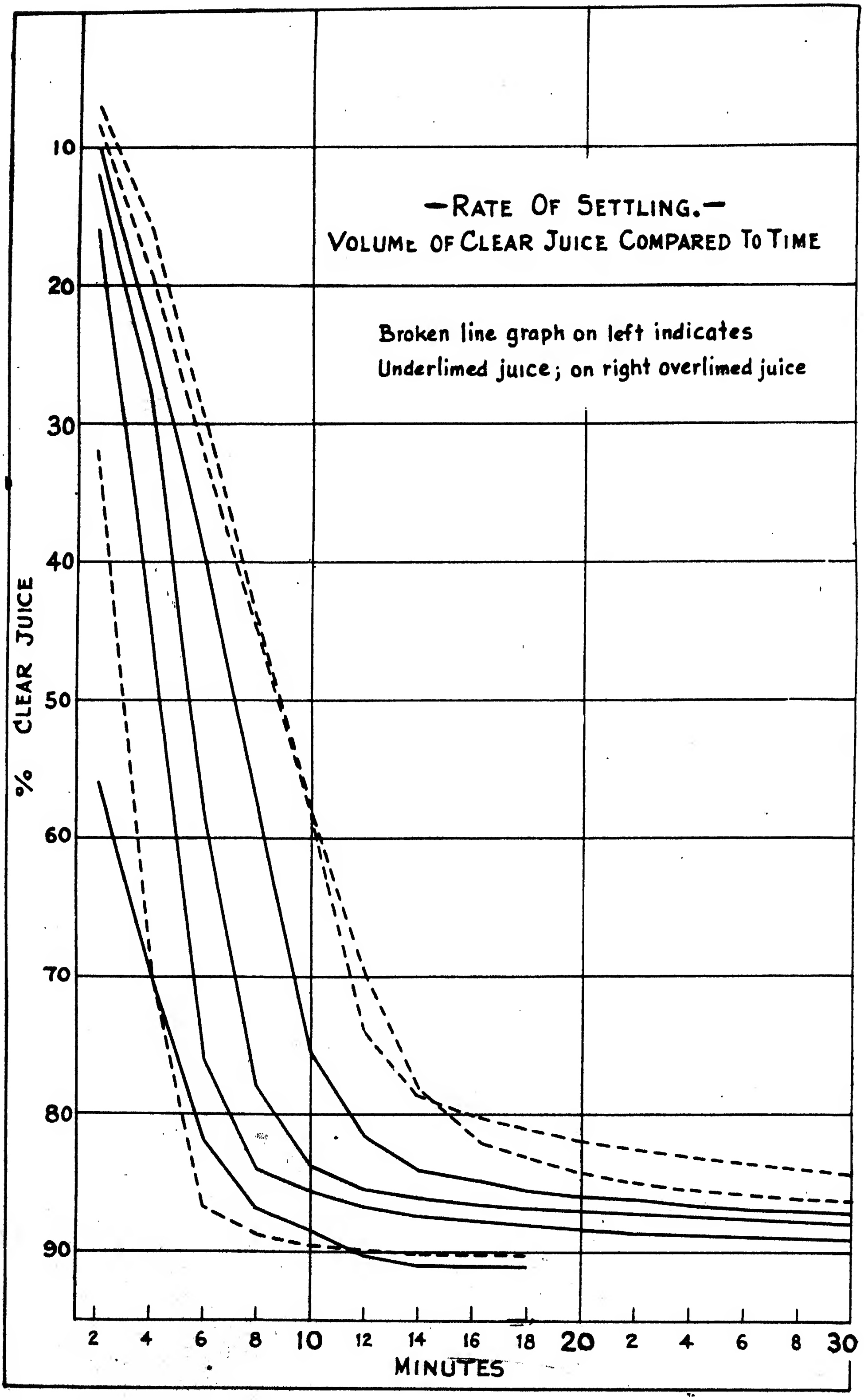
to phenolphthalein. This becomes a limiting factor of the reaction at which clarification may be conducted if there is not available sufficient capacity at the filters to compensate for the increased duty imposed on that station.

Many operators interpret the conditions which exist when clarification is maintained at the optimum reaction as "slow settling." On this point the writer agrees with the opinion expressed by W. R. McAllep that the condition is not actually one of slow settling, but simply one of increased volume of settlings, the precipitate coming to rest and settling to its ultimate volume in approximately the same time required for settling at a less alkaline reaction. Mr. McAllep has prepared the accompanying graph from data furnished by Noel Deerr in his publication, *Cane Sugar*, which fully demonstrates this point. These curves indicate that during the first part of the settling cycle the precipitate follows the physical law pertaining to the fall of bodies through a resistant medium; during this period the graph is practically a straight line until it reaches a so-called "critical point," after which the shrinking or contraction of the volume of settlings becomes quite small and of little practical significance. This data, confirmed by actual observation of the conditions in question under operating conditions, indicates quite clearly that *the solution of the question of increased volume of settlings must be approached on the basis of actual disposal by filtration rather than attempting to reduce this volume by extended settling to equal that obtained with less alkaline clarification.*

Once the precipitate settles to the critical point no material reduction in volume will follow; certainly this reduction will not be proportionate to the extension of time. If sufficient capacity exists to permit holding the juice an hour and a half this should be sufficient to bring the volume of settlings to a practical working minimum; indeed, considerations based on the development of acidity and inversion at the high temperatures normally existing in the settling tanks would indicate that the cycle should not be lengthened much beyond this limit. It would seem more economical, and certainly more consistent with the principles of efficient operation, to provide the remedy by increasing the capacity of the filter station.

A factor of considerable importance as affecting the settling cycle is the disposal of filter press juice. When working with cane juices high in phosphoric acid, at the optimum reaction the volume of filter press juice is likely to amount to fully 20 per cent of the mixed juice. Obviously, if this is taken back to the raw juice for re-settling the duty imposed on the equipment is increased 20-25 per cent, thus reducing the settling cycle by that amount. The practice of returning the filter press juice to the raw juice is defended principally on the ground that this is a safeguard against contaminating the clarified juice through broken filter clothes. This, however, only temporizes with the problem; the real solution must be to so organize the work of the filter press station that it can be depended on to deliver clean juice at all times without danger of allowing dirty juice to re-enter the system. Probably half of the factories now do so in an entirely satisfactory manner, which is ample proof that the scheme is entirely feasible.

The principal objection which may be aimed at the intermittent settling tank is the fact that a considerable portion of the total juice must be decanted from a zone immediately over the mud line. This disadvantage makes itself evident in


—RATE OF SETTLING.—
VOLUME OF CLEAR JUICE COMPARED TO TIME
Broken line graph on left indicates
Underlimed juice; on right overlimed juice
% CLEAR JUICE
10
20
30
40
50
60
70
80
90
2
4
6
8
10
12
14
16
18
20
2
4
6
8
30
MINUTES

many ways. Frequently the juice discharged from the lower draw-off is not so clear as that from the upper valves, due to the fact that the currents set up immediately over the mud line carry over just sufficient mud particles to make the juice turbid, but not sufficient to warrant turning this juice to the mud trough. This disturbance becomes more exaggerated if the rate of draw-off is increased, and to prevent this the tendency is to draw off more slowly from the lower valve than is actually necessary, resulting in a reduction in the efficiency of utilization of settling capacity. In some cases, the writer has seen a third of the total settling tanks in a factory practically out of service because of the slow rate of draw-off from the lower outlets.

Conversely, the principal advantage of the continuous type of settling tank lies in the fact that the juice is drawn off at the maximum distance from the mud line. Despite this fact, however, several installations of continuous settling tanks fail absolutely to deliver juice of equal clarity to that which might be expected from similar clarification procedure with intermittent tanks. In one particular installation with which the writer experimented, both intermittent and continuous settlers were supplied with heated lime juice from a common supply tank; the intermittent tanks never failed to give juice of superior clarity.

With intermittent settling tanks of conventional design, when clarification is carried at even moderate alkalinity, the level of the mud will in almost every case lie between the lower and middle outlets. Many factories follow the practice of drawing off mud through the lower draw-off until clear juice is discharged from this valve, at which time the juice is diverted to the clear juice trough.

The result of this rapid draw-off must certainly be to set up currents within the tank which result in drawing off with the mud a considerable volume of clear juice as well. Much better results should follow if the heavy mud is drawn out through the mud discharge valve, thus lowering the level of the mud line below the lower outlet valve; in this way, since the movement of the juice and mud is in a downward direction, no disturbance should result. If mud to be filtered is drawn only from the bottom valve, the mud or dirty juice trough may be connected to the limed juice receiving tank; the only juice then turned to this trough would be that first drawn off from each valve, and the juice from the lower outlet in the event that it ran dirty through too rapid discharge. By diverting this juice to the mixed juice for re-settling the duty on the filters may be considerably lightened and the ratio of solids to liquid in the settlings may be maintained at a higher figure.

Filter Press Operation

The problem of maintaining clarification at the optimum reaction is in large part a matter of capacity for the filtration of settlings. While it is perfectly obvious that the filter press station should be operated to fullest efficiency, the fact remains that little agreement exists as to the ideal conditions for filter press operation. Filtration as a chemical engineering problem has received considerable attention, but specific data pertaining to the filtration of cane settlings is entirely inadequate to enable us to definitely lay down a series of rules for the conduct of this operation. Assuming that filter press equipment is in good mechanical order, that the frame surfaces are clean and permit proper tightening, that the cocks

are in good tight condition and that the inlet and outlet ports in the frames are free from obstruction, there remain two principal factors on which no agreement seems to exist: First, pressure of filling; second, reaction of the settlings.

The matter of pressure is found to vary among our best factories from as low as 10 lbs. per square inch to as high as 40 lbs. The writer cannot conceive of such radical differences in the filtering characteristics of settlings as to make these extremes *justifiable*; surely both cannot be equally efficient, and yet the fact remains that data is not at hand to definitely demonstrate the efficiency or correctness of either pressure.

While formulas for filtration developed in chemical engineering practice may not be specifically applied to the solution of our problems, they at least indicate the factors involved, and from them we may arrive at an understanding of the most beneficial operating conditions. Filtration may be considered as a flow through a capillary tube, for which the equation shows flow to be proportionate to the pressure and to the fourth power of the radius of the tube, other conditions being equal. With a gelatinous, highly compressible material such as cane mud, it seems quite obvious that the porosity of the cake will be affected by increased pressure; since decreasing the radius of the interstices of the cake one-half will reduce the rate of flow to one-sixteenth, the importance of the appropriate pressure becomes apparent.

When handling solids of crystalline or granular texture, increase of pressure results in almost proportionate increase of filtrate, but with a flocculent precipitate the head may often only be increased a few feet before a contrary result is obtained. Wright, in his text, "Industrial Filtration," says: "The reason that, in practice, the law of increased pressure does not always increase the flow, is found in the fact that in filtration the orifice (i. e., cake porosity) becomes a variable under pressure. For every material there is a pressure above which an increased flow is not obtained, but a decreased flow is had instead. This is known in filtration parlance as the *critical pressure* for that material."

These theoretical considerations are well borne out by observations made under actual working conditions. One factory noted for the excellence of its filter press work as measured by the low polarization of the press cake, employs a gravity head equal to a pressure of 10 lbs. per square inch.

Obviously filter press work must be considered as a combination process of filtration and washing, and filtration proper must proceed in such a way as to leave the resulting cake permeable to water so that excessive time is not required for washing; unless this condition is met, any saving by the use of high pressure is lost through the extended time required for sweetening off the mud. At the factory in question, timing of the filtration cycle over a period of three days gave an average of two and a half hours for filling, and a few minutes over two hours for washing, resulting in a press cake of approximately 1.0 per cent polarization. These results compare favorably with any being secured at other factories and demonstrate the effectiveness of low pressure filling. Ease of washing press cake to a low polarization in a short period may be accepted as an indication of cake porosity, which, in turn, is a measure of the interstices between the solid particles making up the cake; this should indicate a high rate of flow, a condition actually demonstrated by the short filling time quoted.

During the past season the writer had opportunity to experiment with filtration of settlings at two factories, one where the settlings came from juices low in phosphoric acid and were comparatively low in volume, the other from juices moderately high in phosphoric acid and the volume of settlings so high as to constitute a serious problem in clarification.

In the first case, under customary operation, the pressure was allowed to build up to 40 lbs., at the end of the cycle, the filtering cycle varying from three to seven hours; the polarization of the press cake averages approximately 2.5 per cent; nine presses were used and frequently were of insufficient capacity. A centrifugal pump was installed and operated to give 18 lbs. pressure at the presses; the number of presses in service was reduced to the minimum, each press being forced to the limit at the pressure available. Under these conditions, it was found possible to fill the press in somewhat less than three hours, but to reduce the procedure to routine the filling cycle was arbitrarily set at three hours; washing was likewise set at three hours per press. The net effect was to reduce the polarization of the cake to approximately 1.5 per cent, at the same time increasing the capacity of the station to such an extent that usually at least three presses stood empty. The quality of the press work was such that the juice was taken direct to the evaporators and at no time was difficulty experienced with broken cloths or dirty juice.

In the second case, filtration had been conducted at a pressure of 35-40 lbs., with washing following at 50-60 lbs. At this pressure the leakage during washing was so great that the full maceration requirements of the mill were met by the quantity of sweet water produced, amounting to 1,600 per cent on the weight of cake. When the presses were filled by centrifugal pump at 15-20 lbs. pressure, no difficulty was experienced in maintaining a rate of flow equal to that obtained at 40 lbs. The leakage was materially lessened when the washing pressure was reduced to 30 lbs., and the polarization of the cake dropped to about half of that secured on preceding days. Likewise, juice leakage during filling and the danger of broken bags was so reduced as to make it possible to divert the filter press juice direct to the evaporators, a practice previously considered unsafe.

In general, practical data available indicates that the critical pressure for cane settlings is more likely to lie below 20 or 25 lbs. than above, and high pressure does not seem advisable, particularly since this increases the danger of broken bags and thus makes unsafe the practice of returning press juice direct to the evaporators.

Filtration practice, in beet sugar manufacture as well as in other chemical engineering industries, is almost unanimous in favoring the use of centrifugal pumps for press filling, though for pressures up to 15 lbs. most cane factories could conveniently arrange a gravity feed. This is equally satisfactory, but in many cases would perhaps prove as expensive as the installation of a centrifugal pump.

One further factor of considerable importance is the reaction at which filtration is conducted. In many factories the settlings are carried distinctly alkaline to phenolphthalein, while in others no further lime is added to the settlings after the original liming of the mixed juice. Perhaps a slight increase in rate of flow is secured by adding sufficient lime to bring the juice to approximately 8.0-8.5

pH, but other considerations would indicate that this reaction should not be exceeded; at this alkalinity the press juice may be safely mixed with the clarified juice without bringing about a new precipitate, if the original liming has been carried to a reasonable degree. It is interesting to note that experiments conducted locally with a type of filter not previously used on cane mud indicated no increase in rate of flow through heavy liming.

Fine Juice Straining

Extensive laboratory investigations at the Experiment Station showed that during the course of clarification the action of lime and heat on the particles of cush-cush present in the mixed juice brought about the solution of certain noncellulose constituents, resulting in a decrease in purity. The development of the Peck juice strainer, using screen of 100-150 mesh, has been a practical effort to avoid this decrease in purity by removing the major portion of the fine cush-cush usually present. Mechanically, this juice strainer has been successful in removing approximately 50-60 per cent of the suspended matter from the mixed juice but resulting difficulties in filtration of settlings have been so marked, in some cases, as to offset the expected advantages.

Reviewing the situation at this late date, it is evident that the difficulties actually encountered were only to be expected. Filter equipment in use in the various factories was originally installed on the basis of the conventional standards, which, in turn, were developed from actual operating tests with material having the filtration characteristics of settlings containing the usual amount of solids. Removal of these solid particles would obviously change the filtration characteristics in an adverse direction and capacity which previously had been ample would immediately prove insufficient. As a remedy for the increased difficulty of filtration, rather than increase filtering area, an effort was made to change filtering characteristics back to the orginal condition by heavy liming, but this was only partially successful. In any event, the writer believes that this is the wrong direction in which to proceed, because by increasing the alkalinity of the settlings prior to filtration, in all probability the net result is to offset the original advantages obtained by the removal of the cush-cush. Approximately half of the original fiber still remains in the juice after fine straining, and this is in turn concentrated to the settlings; if, however, these settlings are now maintained at a distinct alkalinity to phenolphthalein half the original cush-cush is subjected to many times the severity of chemical treatment which the process is designed to avoid. It is not improbable that as much material is dissolved from the cush-cush in the settlings under the new conditions as from the full amount of fiber present without fine-screening at the lower alkalinity of settlings carried under normal conditions.

The writer believes that the scheme in operation at Pioneer Mill represents the ultimate solution of the fine straining problem under current conditions, when working with plate and frame presses of the present type. Here the material screened from the juice is returned to the settlings; consequently, there is no change in the filtering characteristics of the scums; filtration proceeds without addition of extra lime, and the net gain secured by the removal of half the cush-

cush during the heating and settling cycle (the period of highest temperature and highest reaction) is actually retained.

Lime Salts

Experimental data shows that after the reaction of the juice passes the optimum point, there is a material increase in lime salts. The difficulty in boiling juices resulting from alkaline clarification, which some operators consider an objection to so-called "higher liming," does not seem to be actually corroborated by facts, since a great many factories proceed at the optimum reaction without noting difficulty in boiling. The question probably resolves itself into proper cleaning of heating surfaces, and if this is done efficiently, satisfactory boiling should be obtained. The use of a small amount of soda ash in the juice is recognized as a material aid in keeping the heating surfaces clean and the expense can probably be offset by a corresponding reduction in the amount of caustic soda necessary for boiling out of evaporators and pans.

Clarification in Factories Operating Only on Single Shift

In factories which operate twelve hours per day, necessitating the hold-over of juices for twelve hours, clarification procedure becomes a problem of special importance, for here, unless proper precautions are taken, losses through inversion during the hold-over period may reach serious proportions.

Sucrose loss during hold-over may take place for two reasons: First, due to the development of acidity through heat, which may cause the juice to reach a reaction at which the rate of inversion becomes sufficiently rapid to cause material loss of sucrose; or second, through bacterial activity when the temperature reaches a level at which this may take place.

Data made available through clarification studies conducted at the Experiment Station show a striking difference in the rate of acidity development at various temperatures; at 210° F., the development of acidity proceeds at approximately four times the rate found at 180° F. For juices to be held over night, the obvious procedure is to reduce the temperature to the limit imposed by other operating considerations. Complete coagulation of proteids is best secured by heating to a minimum at 180° F.; on the other hand, 165° F., has been set as the safe lower limit to prevent the activity of bacteria and organisms which are found in cane juices. Thus the primary requirements for temperature control are that the original temperature should not be less than 180°, and sufficiently high so that the final temperature will not fall below 165°. With juice to be held over the week-end for a period of thirty-six hours, if the temperature loss by radiation is three-quarters of a degree per hour, the initial temperature must not be less than 192° F., and with a suitable factor of safety the heating would ordinarily be carried at 200° F. At this temperature, however, the development of acidity would proceed at such a rate the juice limed to the optimum reaction of 8.0-8.3 would no doubt have a final reaction low enough to cause appreciable loss through inversion. If, on the other hand, the insulation of the settling tanks was such as to reduce the temperature loss to one-third of a degree per hour, an initial temperature of 185° would be sufficient to assure a final temperature above the bacterial danger point,

and at this temperature the final reaction would be such as to exclude the liability of appreciable inversion.

These conditions are well illustrated by actual data obtained at the factory of Hawaiian Agricultural Company during the past season. At this factory the tanks are insulated on the sides with the customary 1½" magnesia blocks, and in addition the bottom cone is now covered with a 2" layer of asbestos cement, with the top completely sealed in with a similar covering.

Previous to following a systematic plan of reducing the temperature, the juice to be held over was treated with *double* the quantity of lime required during regular operation to bring the juice to slight alkalinity to phenolphthalein in the cold juice, and in addition a considerable quantity of formalin was added. At the end of 36 hours this juice had a temperature of 190-195° F., but the reaction was reduced to 5.4-5.8 pH; at this hydrogen ion concentration the loss through inversion undoubtedly became serious.

When the temperature of juices held over was reduced, the reaction of the heated juice at the time of filling the settling tanks was carried at only 8.0 pH, no variation being made from the liming as practiced during the regular day's operation, and in addition the use of formalin was discontinued. The following typical data will demonstrate the effect:

	Temperatures in ° F.			Hydrogen ion	Concentration
Tank	Initial	Final	Drop	Initial	Final
4	182	165	17	8.0	7.3
5	184	166	18	8.0	7.3
6	183	167	16	8.0	7.3
7	182	166	16	8.0	7.4
8	186	168	18	8.0	7.2

Total time of hold-over—38 hours.

At this final reaction, experimental data indicates that the possibility of loss by inversion is negligible as a practical operating factor. In over-night hold-overs, the same principles apply. At the factory in question, no change in liming was made in the juices; this has the special advantage that the conditions for ideal clarification are maintained even for the juices to be held over. Under the previous system, these juices, amounting to perhaps 15 per cent of the total production, were seriously overlimed, with the attendant darkening in color and destruction of glucose, *without eliminating the losses by inversion.* Daily measurements of initial and final temperatures, together with pH values, showed that the temperature loss could be reduced to approximately 0.4° or less per hour, and that by liming only to slight pink to phenolphthalein in the cold juice the final reaction would be approximately 7.4-7.6 pH; this may be considered entirely satisfactory.

Special precautions should be taken to avoid holding over any quantity of juice in partly filled tanks, since under these conditions the temperature loss is much more rapid than in full tanks. Some factories follow the practice of leaving the settlings in the tanks on the last two or three settlers emptied before closing down; while this is, of course, much better than dropping the settlings to uninsulated tanks, an even better scheme is to make suitable piping connections so that these settlings may all be pumped back into one settling tank and there held during the shut-down period.

For factories operating one shift, the writer believes that to equip each settling tank with an individual thermometer is one of the best investments that could be made; this gives the operator a chance to know definitely what is being done, a basis for judging the effectiveness of the insulation, and a control on the accuracy with which the over-all plan is being followed. A satisfactory thermometer may be purchased for $3.00. Measurement of pH values on each individual tank of juice held over will in many cases throw a good deal of light on the source of undetermined losses and will effectively demonstrate the necessity of exact temperature and reaction control. The development of color charts for the measurement of hydrogen ion concentration now makes possible an accuracy of control that heretofore has not been possible, and the factory operator who fails to take advantage of this opportunity to put the control of juice preservation conditions on a scientific and reliable basis is not availing himself of what is without doubt the most important development in sugar factory control made within a considerable period. Without considering unimportant theoretical objections which might be made against the color charts, the fact remains that their use makes possible a definite measurement of conditions of acidity and alkalinity which may in turn be compared to definite standards of procedure. As a result of a great deal of experimental work it can be said with certainty that if the reaction of the juice is maintained at or above 7.5 pH, inversion as a practical factor will not exist. This leaves little to be desired from the standpoint of developing a working program for the operation of a sugar factory; it simply resolves itself to maintaining proper initial conditions of temperature and reaction to the end that the final hydrogen ion concentration will lie above the danger point. The color charts and their use are actually so simplified that ordinary laboratory boys should be quite capable of making the routine observations; an intelligent man in charge of liming should have no difficulty in measuring the reaction of the heated juice and basing the liming on his results. To forestall the objection that someone is sure to make to this statement, it is obvious that none but an intelligent man should be permitted to have charge of the liming.

Insulation on settling tanks has usually been confined to covering the sides and seemed primarily for the purpose of preventing convection currents being set up by cooling at the sides. In the light of our new information, the writer feels that insulation becomes a matter of vital importance, especially in factories which are obliged to hold juice over for some twelve hours out of each day. An effective and economical way of insulating the bottoms of the tanks is to enclose the entire area with "Celotex," though a layer of asbestos on the cone would probably be well justified. For the tops a 2-3″ layer of asbestos plaster is recommended. With efficient insulation the temperature drop should be less than 0.5° F., per hour, which makes it possible to follow such a scheme as is outlined here. The importance of this phase of factory work has been so thoroughly demonstrated to the writer in the course of factory experiments this season as to prompt the expression of opinion that a very material possibility for increase in recovery lies open to most of the smaller factories at very small cost by proceeding in this direction. Nothing short of perfect conditions for juice preservation should be tolerated.

pH and Turbidity*

By W. K. ORTH

Only two members of our Association contributed to the report on pH and turbidity determinations. This is disappointing since the matter of pH measurement is of vital interest this year.

J. H. Pratt, of Pioneer Mill, considers the pH control of clarification as one of the most important advances we have made in the boiling house in recent years. He says: "From what we have done so far, I am convinced that we gained a lot of benefit." We, too, at Ewa, are certain that better clarification is due to closer attention to liming as a result of the pH determinations and turbidity measurements.

As routine, we determine pH values of the limed mixed juice and of the resulting clarified juice together with the turbidity figure in clarified juice every time a sample is taken as an average on 12 samples per day. Those interested are informed of the results as soon as possible, often over the phone.

The figures for mixed juice varied from 7.3 to 9.2, the low figure from 7.3 to 8.0 being recorded in 8 per cent of the samples, from 8.0 to 8.5 in 50 per cent, from 8.5 to 9.0 in 21 per cent, over 9.0 in 11 per cent of the juice tested. In the clarified juice the low figure was 6.9, the highest 8.2. It is 6.9—7.5 in 58 per cent, above in 42 per cent of the samples.

For thirty days, determinations were run on samples of all factory products as they follow each other in the process. The average figures found are:

Mixed Juice	Clarified Juice	Syrup	A Massecuite	A Molasses	B Massecuite	B Molasses	2nd Massecuite	Final Molasses
818	7.61	7.51	6.84	6.76	6.76	6.77	6.70	6.33

Six tests were made to find if any deterioration took place during the boiling of low grade, with these results:

Entering Molasses	After 2 hours boiling	4 hours	6 hours	12 hours	After 7 days
6.7	6.7	6.7	6.7	6.7	6.45

Glucose determination likewise did not indicate inversion.

A number of further tests are recorded, namely, averages of daily compilation of purities for mixed juice and clarified juice, CaO and P_2O_5 (grams per liter) in mixed juice and clarified juice, the increase in purity from mixed juice to clarified juice, and from mixed juice to syrup, the turpidity figure, the pH in limed mixed juice and in the resulting clarified juice.

Some of these follow. Attempts were also made to show the influence of P_2O_5 and CaO on pH determinations and turbidity measurements. By turbidity is meant a measure in degrees of millimeters, starting with zero and advancing to

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

higher figures with greater clearness of the liquid under observation. A higher "turbidity" figure means in our case clearer juice. The instrument used is the Kopke turbidimeter, consisting of a small graduated glass tube ⅛" in diameter and 6 cm. long, to the zero end of which is attached a white porcelain plate 4 cm. in diameter. This is marked with fine black lines, forming 2 mm. squares. This plate is immersed in the juice until the black lines become just invisible. The column of juice in the glass tube, corresponding to this point, shows on its upper end the turbidity figure.

No. of tests	P_2O_5 grams per liter in mixed juice	pH difference mixed juice to clarified juice
49	.316	0.92
25	.372	0.85
72	.493	0.82

P_2O_5 grams per liter in clarified juice	pH difference mixed to clarified juice	Turbidity
.0298	1.05	3.22
.0350	0.91	3.37
.0435	0.84	3.55

P_2O_5 grams per liter in mixed juice	Turbidity	Tests
.289	3.10	20
.324	3.30	83
.403	3.61	60

CaO grams per liter in mixed juice	Turbidity	Tests
.1626	3.34	48
.2265	3.40	58
.3045	3.58	19

pH in mixed juice	pH in corresponding clarified juice	Tests
8.03	7.22	30
8.22	7.48	68
8.68	7.65	50

The following shows the relation between P_2O_5 in mixed juice and corresponding clarified juice.

P_2O_5 mixed juice	P_2O_5 clarified juice	Tests
.292	.0214	30
.304	.0392	38
.356	.0433	38
.459	.0604	33
.492	.0696	30

Purity of mixed juice	Turbidity	Tests
81.2	3.38	25
83.4	3.46	35
84.8	3.57	38
85.7	3.65	18

More CaO in mixed juice than in clarified juice	pH difference	Tests
.1227	0.82	33
.1990	0.91	30
.2645	1.03	27
.3610	1.09	20

Difference pH mixed juice to clarified juice	Increase in purity mixed to clarified juice	Tests
1.01	1.72	20
0.97	1.89	35
0.81	2.07	40

The P_2O_5 content of the juice affects the turbidity as shown below:

P_2O_5 grams per liter Mixed juice	Turbidity	Tests
.289	3.1	20
.324	3.3	30
.371	3.6	60
.431	3.6	50
.450	3.6	20

Mixed juices were limed to pH 8.6 in the cold, heated to boiling and then let stand in glass cylinders for varying periods of time, drawing the supernatant liquid off so as to show a progressive increase in clarity. The Kopke figure rises from 2.0 to 7.5, the pH of clarified juice remaning around 8.3.

In another test the Kopke figure in both the hot and cold juice rises from 2.2 to 4.7 with pH in the clarified juice 8.3. The purities rise in the first test from 85.05 to 86.63, in the second from 81.37 to 84.23. A general relation is clearly shown between increase in purity and turbidity. This is substantiated by figures over the whole season.

Purity increase	Kopke
0.86	3.3
1.82	3.5
2.53	3.6

Inasmuch as this turbidity is due to suspended precipitate in the juice which affects the Brix hydrometer, the purity changes must be so taken. Nevertheless, turbid juice must have some influence on the viscosity of low grade and on the filtration rate. The fact that we have drawn off juice from the top valves on the settlers, of Kopke between 6 and 7, yet rarely run over 4 in our composite, shows there may be room for improvement in that direction.

Methods

The methods used at Ewa of estimation of hydrogen ion concentration have been various, new ones being tried as they became known, to find the best for our conditions. For the greatest part of the season, we employed the method described as follows:

Our method of estimating hydrogen ion concentration is based on the fact that the pH values are but slightly affected by dilution. Thus, taking juice as an example, if we dilute a given volume of juice with a given volume of distilled water and compare this with the same volume of juice diluted in the same proportion with buffer solution, using, of course, the appropriate indicator, we obtain a color match only if the pH of the juice and the pH of the buffer solution in question correspond.

The following remarks of S. G. W. Farrell, *International Sugar Journal,* Vol. XXVIII, p. 141, may be quoted here:

With buffered solutions such as cane juice, which contain protein, amino acid, amides, phosphates, etc., it is possible to dilute as much as 5 fold without appreciably altering the hydrogen ion concentration, particularly if this is in the neighborhood of pH 7.0.

Continuing the description of our method, if this is not so, we shall have varying shades depending on whether the pH of the buffer solution in question is above or below that of the juice. Since sugar house liquors in general show buffer action themselves, it is absolutely necessary that our standards be well buffered.

At the above mentioned place in the *International Sugar Journal,* we find:

In Natal, Uba juice is more buffered than the juice in Mauritius. In both countries there is an increase of hydrogen ion concentration between the cold limed juice and the hot clear juice. The average increase in pH is 0.6 for Natal and 0.3 for Mauritius:

Limed juice pH 6.9, clarified 6.3.
Limed juice pH 7.0, clarified 6.7.

The increase in hydrogen concentration is probably due to the coagulation of some of the albumen in heating. The albumen is the principal buffer in the cane juice, and when it is removed, there is greater association of the acids in the juice and its pH sinks.

To proceed with our Ewa method: Using clarified juice as an example, four drops of juice are dropped into each spot of a porcelain test plate, to one spot add 8 drops of distilled water (or better M/5 K Cl), to the others, add 8 drops each of buffer solution, covering the probable range, say, pH 7.2 to pH 8.0, in intervals of 0.2. Add one drop of 0.04 per cent phenol red solution, stir with a small glass rod and compare. One of the buffered solutions will match the unknown, or it will come between two of the buffered solutions, unless the range is incorrect. The drops must be uniform in size, as much as possible.

Our buffer solutions are made according to Clark & Lubs Standards, using phtalate—NaO_4 mixtures. This method is applied with variation to raw juice, syrup or even to molasses with some success. The accuracy depends entirely on the buffer solutions. Once standardized, this should not offer objectionable features. It is desirable to standardize them by the electro-metric method.

Our buffer solutions are made in concentration M/2 instead of M/5, as given by Clark. This is done because in some cases, the buffer action of mixed juice was strong enough to throw the M/5 buffers off for a wide range so that the pH determination became indefinite. We make indicators as described by Clark & Lubs, but in concentrations of 0.10 per cent and 0.05 per cent, corresponding to their 0.04 per cent and 0.02 per cent. The reason is that only one drop is needed.

This method which was worked out with great diligence and care by our Mr. Bond, gave indeed very satisfactory results, but we admit is more difficult of application for the average sugar laboratory than the method sent to the plantations by the Experiment Station, H. S. P. A.

Their first set of color charts was carefully compared with our system with the following results:

2 Observers	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day	8th Day	9th Day	Avg.
Max. Variation, H. S. P. A.	0.2	0.3	0.1	0.4	0.3	0.3	0.3	0.3	0.4	0.3
Max. Variation, Ewa	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Variation, Ewa-H. S. P. A.	0.5	0.7	0.4	0.5	0.6	0.8	0.4	0.7	0.6	0.6
Mix. Juice Avg., H. S. P. A.	8.0	8.4	7.5	8.4	8.4	8.5	8.4	8.4	8.2	8.24
Clar. Juice Avg., H. S. P. A.	8.1	7.3	7.1	7.2	7.4	7.3	7.7	8.0	7.7	7.53
Mixed Juice, Ewa	8.1	8.8	7.3	8.7	8.7	8.8	8.6	8.5	8.4	8.43
Clarified Juice, Ewa	8.4	7.2	6.9	7.1	7.1	7.3	7.8	8.2	7.9	7.54
Number of Tests	3	4	4	4	4	5	5	5	4	38

We continued to prefer our method. But, when buffer solutions were restandardized by the new potentiometer at the Experiment Station and, after new charts had been furnished, the results of comparisons were much closer and quite satisfactory:

DURING DAY								DURING NIGHT				Observer
1				2				3				
Ewa		Exp. Stn.		Ewa		Exp. Stn.		Ewa		Exp. Stn.		50 Tests
Mix.	Cl.	Mix.	Cl.	Mix.	Cl.	Mix.	Cl.	Mix.	Cl.	Mix.	Cl.	
8.33	7.35	8.33	7.39	8.22	7.36	8.24	7.39	8.24	7.15	8.22	7.13	
Same juice				Same juice				Same juice				

Toward the end of the season we received a La Motte Hydrogen Ion Comparator set with the following standards:

Brom cresol purple	5.4—6.6
Phenol red	6.8—8.4
Phenol blue	8.0—9.6

The whole outfit with 30 standards, graduated test tubes and graduated trappers plus comparator box cost but $9.00.

The results with this apparatus were very satisfactory and the closest concord between the different observers was found. As the apparatus was in use for only three weeks, a final judgment cannot be given. It is very promising.

In the *International Sugar Journal* of May, 1925, are found descriptions of H. C. Prinsen Geerligs and Prof. Dr. Herzfeld, for the use of test papers with the following indicators:

Brom cresol purple, brom thymol blue, corallin and phenol red. Dr. Herzfeld indorses this method as much simpler than determination of pH values described by American chemists, using buffer solutions. The papers are used in factories that employ the carbonatation process, where a close observance of the "end points" is essential.

We, at Ewa, have tried home-made brom cresol purple and phenol red paper, so far, in a desultory way, with disappointing results. We intend to test the possibilities in a more whole-hearted way during next season.

Finally, I beg to mention the latest directions sent out by the Experiment Station, dated July 22, 1925. They are so complete and so easy to follow that every laboratory should have something to say on pH determinations for the meeting of next year.

The reports of J. H. Pratt, of Pioneer Mill Company, F. D. Bolte, of Hutchinson Sugar Company, and E. Haneberg, of Olowalu Company, follow. I have no other comment to make, but to say that they are very interesting and highly welcome to fill my meager paper.

Mr. Pratt comments as follows:

We used pH control during the last thirteen weeks of the crop. Comparisons between this period and the other two-thirds of the year are not very satisfactory, mainly for two reasons. The rate of grinding started to slow up soon after this work was started. Out of an available 75 days, we ground on 69 and only averaged 17.2 hours per day. In June, we encountered four or five fields, the juice from which was very difficult to handle at both the settling tanks and presses and which, for several weeks, almost doubled our usual percentage of mud on cane. My comparisons are, therefore, based on the first five weeks that we had this work on a routine basis and before either of these difficulties became serious.

It took almost two weeks to educate the men at the liming and settling tanks to the meaning and importance of the pH figures, but, after this, the results of the work were immediately apparent. During these first two weeks, 72.3 per cent of the settling tanks were 7.7 pH or higher, while during the succeeding five weeks the percentage rose to 94.5. The rise in purity from the mixed juice to syrup showed an increase of .3, the purities of the individual syrup and clarified juice samples were much more consistent than heretofore, the amount of lime used went up 13 per cent and the amount of press cake showed a corresponding increase (12 per cent). The polarization of the mud showed a decrease of .1.

During the thirteen weeks, we tested 2257 settling tanks (92 per cent of the number filled), 530 samples of "cold limed juice," 683 press juice, and 437 of syrup. This gives an average of two clarified juice samples an hour, 1 mixed and 1 press juice every two hours, and a syrup every three hours. The juices are all grab samples, while the syrup is our regular three-hour composite (without formalin). We use a dilution of from 1 to 3½ or 4 for the juices and of 1 to 16 or 20 for the syrup. During most of the period, these dilutions were made with distilled water. As this was always slightly acid, it was found to be quite as simple to neutralize ordinary tap water. Our tap water reads about 7.8 pH.

Owing to the amount of color in our massecuites and molasses, we found it very hard to get accurate readings without very high dilutions. The few samples which we were able to read at 1 to 50 dilutions, gave the following results: "A" molasses 7.28, "B" molasses 7.18, "C" molasses 7.10, and waste molasses 7.00 pH. Our low grade sugar is also about 7.0 pH. Twelve samples of wash water from the presses averaged 7.8 pH.

A very important use of these indicators is in testing the liming of tanks of juices which are to be held over shut-downs. The first four weeks that we were using the pH sets, the juice held over Sundays dropped from 8.43 to 7.32 (on the clear or filtered juice) in 25 hours. By testing every tank that was to be held over a shut-down or even a couple of hours, we were able to keep the juice held over at about the same pH as when running steadily. Quite often we tried the pH of the juice at intervals of three or four hours during a long shut-down. The average of 107 tanks which were held over a period of at least three hours longer than the usual settling time was 7.50, and omitting the samples from the first few weeks, would considerably improve this average.

The following are the weekly averages of our samples:

	Clarified		Limed		Press		Syrup	
Week ending	No.	pH	No.	pH	No.	pH	No.	pH
April 11.........	156	7.79	8	8.84	3	7.47	28	7.69
" 18.........	151	7.77	25	8.83	7	7.60	30	7.67
" 25.........	217	7.98	31	8.85	29	7.81	39	7.75
May 2.........	192	8.00	38	8.89	43	7.78	42	7.74
" 9.........	193	7.94	50	8.85	50	7.77	43	7.69
" 16.........	163	8.00	80	8.88	78	7.76	34	7.64
" 23.........	189	7.93	67	8.87	63	7.76	37	7.49
" 30.........	228	7.94	60	8.95	106	7.81	39	7.55
June 6.........	151	7.90	12	8.83	53	7.67	23	7.42
" 13.........	184	7.92	35	8.89	78	8.05	33	7.57
" 20.........	155	7.82	30	8.92	69	7.78	32	7.56
" 27.........	194	7.73	63	8.95	81	7.64	46	7.52
July 1.........	84	7.83	31	8.69	23	7.64	11	7.52
True Average....	2257	7.90	530	8.88	683	7.78	437	7.61
Arith. Mean		7.890		8.865		7.733		7.600

I consider that pH control of clarification is one of the most important advances we have made in the boiling house in recent years.

Mr. Bolte's report follows:

We have been determining the pH values of our clarified juice, press juice and syrup with the four indicators and color charts furnished us by the H. S. P. A., Experiment Station, since May of this year, i. e., brom thymol blue, phenol red, cresol red and thymol blue.

A request for an indicator and chart of higher pH range, say, methyl red or brom phenol blue, with pH ranges from 4.6 to 6.0 and 3.0 to 4.6, as given by Clark and Lubs on page 80 (Table 6), was turned down by the Experiment Station, and we have not procured buffer solutions to make a scale for ourselves yet.

With the above available four indicators, we have determined the pH values regularly on our regular 3-hour composite samples, and below you will find the average pH values for the three juices tested, viz.:

Month	Clarified Juice	Press Juice	Syrup
May	7.34	7.56	7.07
June	6.86	7.17	6.71
July	7.03	7.19	6.87
August	7.09	7.43	7.02
True average	7.09	7.35	6.92

We have endeavored to lime our mixed juice to a slight phenol alkalinity at the juice scales, or to 8.4 pH, resulting in above values for the subsequent juices.

We found at first that the formaldehyde added to the sample buckets to preserve our juices gave us wrong pH values, so we discontinued adding formaldehyde to our sample buckets with no influence on our purities and giving us correct pH values from our regular composite juice samples.

Turbidity determinations with the Kopke turbidimeter have been made here for the last two years regularly on all our juice samples with these results:

	Clarified Juice	Press Juice	Syrup (Dilution 1/5)
Average for 1924-25	2.76	3.70	1.75
January to March	3.02	3.81	1.77
April	3.68	3.96	1.93
May	4.09	6.11	2.68
June	3.63	4.34	2.62
July	2.95	3.36	2.31
August	2.47	3.17	2.06
True average (to date)	3.21	3.93	2.19

Better turbidity figures for 1925 against 1924 are due principally to grinding more Yellow Caledonia cane this year, against more Rose Bamboo cane last year.

	Per Cent Yellow Caledonia	Per Cent Rose Bamboo
1924	37	63
1925 (to date)	64	36

The juice of Yellow Caledonia cane clarifies better than that of Rose Bamboo cane, due to a much higher phosphoric acid content, and requires more lime for tempering than do the juices of Rose Bamboo.

The average phosphoric acid content of juices for 1925 follows:

Yellow Caledonia cane	0.063%
Rose Bamboo cane	0.027%

Regarding improvements on the methods, would suggest that the Experiment Station prepare and furnish methyl red and brom phenol blue indicators and color charts for the determination of higher pH values in unlimed mixed juice and field juices, too.

Mr. Haneberg submitted the following report:

I am enclosing herewith a tabulation of all my data on temperature drop in juices held over and on the pH drop. I have no record of the atmospheric temperatures and wind conditions which perhaps would explain some of the differences in drop per hour on consecutive days.

You will also find it strange, as I do, that the average drop in pH is not proportional to the drop in temperature. For instance:

No. 5 shows an average temperature drop of 0.397 and pH 0.511.

No. 4 shows an average temperature drop of 0.452 and pH 0.499

I can only assure you that readings were taken very carefully and with the expectation of having them doubted.

We proved to our own fullest satisfaction that the old bagasse filling was a better and far less expensive insulation than the 85 per cent magnesia blocks, which appear to be inferior to Celotex fiber board.

Of course, it is necessary to remove the bagasse every 3 and 4 years and to paint the tanks, but that must also be done with magnesia insulation if any moisture gets into it.

Our tests further proved conclusively that it is absolutely necessary to cover the tops of the tanks to prevent an excessive drop of temperature. We have spent, annually, about $400 for formalin, and since we have covered the tops of our tanks, we have not used a drop of it.

A tabulation too long for publication gave some interesting data on temperature drop over the hold-over period, with pH measurements on the same juice. A digest of this data follows:

TEMPERATURE DROP F° PER HOUR

	Settling Tank Number					
	1	2	3	4	5	6
March 27 to April 7, 1925........	,41	.36	.44	.34	.27	.50
May 6 to June 8, 1925..........	.62	.52	.52	.45	.40	.54

All tanks in T. & G. casing, with 4" layer of bagasse surrounding.

During the second period, tank No. 1 was covered with 1½", 85 per cent magnesia blocks; No. 2 was covered with three ½" layers of Celotex bagasse board and wood lagging.

In all cases, juice temperature was reduced to 180-200° F.; juice reaction was carried to show phenolphathalein alkalinity and the reaction of the juice was uniformly satisfactory at the end of the hold-over.

Short Term Contracts on Hawaiian Plantations*

By J. H. Midkiff

Labor is one of the greatest, if not the greatest, items of expense on all the Hawaiian plantations. From the time the land is cleared and the breaking plow turns the first furrow in preparation for the planting until the bagged sugar is shipped from the plantation, the problem of doing every operation as cheaply and economically as possible is extremely important. In fact, the difference between a profit and a loss on the sugar produced rests, to a very great extent, in the hands of the men who are handling the labor.

Satisfactory handling of labor is particularly difficult at this time for two reasons: first, labor is universally demanding more and more for what it does (and Hawaii is no exception to this rule), and, second, the prices that can be obtained for sugar at present make it necessary to do our work cheaper than formerly, if we hope to keep the red ink off our books.

It is probably not self-satisfaction for us to say that Hawaii leads the world in efficient sugar production. Results show that nowhere else can such large returns per acre be found as are common today in Hawaii. Our systems of cultivation, our knowledge of fertilizer and water requirements, our methods of combating insect pests, plant diseases, etc., all show that much time has been spent to good advantage in solving those problems. But it might be pointed out that we have not been quite so successful in improving our methods of handling labor.

Suggestions for improving labor conditions have not been altogether lacking, either. Labor unions and labor agitators simply say: "More pay and shorter hours is all that is needed." They are looking at one side of the question only. They do not realize that many times an increase in rates, *without a proportionate increase in results,* would be absolutely disastrous to the employers. Employers, on the other hand, have also often been to blame in that they have not given enough thought to methods of bettering labor conditions. Sometimes labor can be given a chance to

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make more without raising the net cost of the finished product. *Changes that affect labor must be mutually beneficial to the employers and the laborers if they are to be really and permanently successful.*

Day Work Labor

For many years a large part of our plantation work has been done by day labor. An overseer in charge of a gang simply got what he could out of the men. While good work can be done in this manner, the system is expensive, even though the base rate per day may be fair, because the incentive for any man to do more work than any other man is lacking. It is the natural thing for the average worker to get through the day as easily as possible, doing no more work than he has to, to "get by" with the overseer. Under these conditions, it is a pretty good testimony to the efficiency of the overseer when good, economical work is done.

Long Term Contracts

The cultivation, that is, the weeding and irrigating, of the growing cane crops has been done in Hawaii for a good many years past by long term contracts. Certain men are given so many cents per ton to cultivate a given area of cane, usually from the time of the second or third irrigation until the water is taken off of the crop. On unirrigated cane the labor is continued, of course, until the cane has reached maturity.

The long term contract is good because it furnishes an incentive to the men to do good work and to stick to the job until the crop is produced. Every one realizes that the better he works and the more cane he raises, the more money he makes. It is doubtful if, under our present labor conditions, a better system of cultivating the cane than this will be found.

But there are hundreds of jobs on a plantation that can not be included in the long term contract. The planting of the cane, getting a field in condition to give to the long term contractors, extra help in hoeing the cane when the work is so great that the long term contractors can not handle it all, ditching, fencing, harvesting, and many other jobs, all have to be done by some system other than by long term contract.

The "Ukupau" System

To get these many jobs done as efficiently as possible, someone hit upon the "ukupau" system a few years ago. By this plan the men are told that they may go home as soon as they have done a certain definite amount of work—hoed so many lines of cane, or dug so many post holes, for instance. This system had a very strong appeal to many of the Filipinos in the early days. Getting home early, a few years ago, seemed to be more of a consideration to them than earning more money. But as the proportion of family men increased, and as a better class of men of this nationality began seeking employment here, higher pay became more important to them than simply going home early.

The Short Term Contract

The short term contract, or the individual contract, whereby each individual man is paid for what he himself actually does, regardless of the pay of the other

men in the gang, is a natural step in the right direction; a system whereby an attempt is made to help the men who want to help themselves; a method of giving men a chance to receive more money, provided they in turn are willing to produce more for the plantation.

To find out just how far this short term contract system has advanced throughout the Territory, questionnaires were sent to all the agricultural members of the Association of Hawaiian Sugar Technologists, asking them to give their rates, opinions, and suggestions for improving short term contracts. The concensus was that the short term contract is the solution to our greatest labor problem. In the following paragraphs are the reasons advanced by these men, who are handling a large part of the labor on our plantations, why short term contracts are good. The opinions given by other men are in quotation marks.

Reasons Why Short Term Contracts Improve Our Labor Conditions

1. There is a greater incentive for laborers to work harder and earn more money.

2. A good laborer gets what he himself actually earns. His earnings are not held down by loafers or malcontents in the gang.

3. Short term contracts are cheaper for plantations, because:

   A. Fewer men do more work and the overhead is cut down.

   B. Important work is done in a shorter time. Often a weeding, for instance, speeded up by contract, gives the cane a longer and better growing period uninterrupted by weeds.

4. "Fifty per cent more work accomplished."

5. "I believe short term contract to be the best. It takes less supervision and gets more work out of the men. At the present time Filipinos seem to take more to ukupau or day work, but I believe this will change as soon as they get onto the work and get a better idea of what a job is worth."

6. "The main advantage in short term contract is that the men work harder, therefore get the work done faster. Even though the cost per acre is the same as ukupau or day work, you are able to get more work done in the same length of time."

7. "Use short term contract where possible (except in irrigation, which should be long term contract). One-third more work is gotten from men who have something to work for. There are no special drawbacks, provided men have a reasonable price for their work, a good luna to see that the work is reasonably well done, and one who can keep them interested in their work."

8. "Puts laborer on his own. Short term contracts help in keeping good loading and cutting gangs together in the off-season."

9. "The advantages of short term contract are the ability to get work done faster with fewer men, thus getting over your fields oftener and, also, probably creating a better feeling among the laborers, as they not only make more money per day but get home earlier. This getting home early is one of the main factors with the Filipino."

10. "Men work harder. The pay is better distributed. Have chance to weed out poor men. Overseers watch class of work and do not have to urge men on."

11. "My records show that short term contracts have given us a gain of 20 to 25 per cent increase in daily work per man with a reduction in cost per unit of 10 to 12 per cent."

Disadvantages of Short Term Contracts

It is unreasonable to suppose that all men should see things in the same light. In the following paragraphs are quoted a number of objections voiced to short term contracts. But most of the men answering these questionnaires, even though they pointed out the following drawbacks, were in favor of the new plan. Here is what they said:

1. Men get to liking short term contracts so well they do not like to take the all-important long term contract.
2. "Apt to be kapulu or careless."
3. "Have found contract plowing and mouldboarding very irregular."
4. "Requires more supervision by section lunas."
5. "Where we have no long term contracts, we find short term contracts in big cane are unsatisfactory. Last year we let out quite a number of contracts at from $1.00 to $1.50 per acre, but found that the men were inclined to take too much water and waste a lot. Where we have to pay for water, we find it cheaper to do this job by day work."
6. "The drawbacks are rough work and the inefficiency of plantation lunas to give correct rates."
7. "When labor is plentiful we believe we get better work by day work than by contract as far as cultivation work goes. Our experience with short term contract hoeing, for instance, is that you get more work out of the men but the work is not done as well as by day labor. The second hoeing has to be done much earlier when the first hoeing was done by contract. We would prefer the ukupau system rather than fixing a rate so much per acre."
8. "The disadvantage is usually poorer work, as the men are hurrying over the job in an effort to get the most they can. In plain words, the main trouble is 'kapula' work, as the main effort is quantity, not quality.'
9. "Requires close supervision to check overseers. Uneven conditions make it hard to determine price."

Suggestions For Improving Our Methods of Handling Short Term Contracts

A great many valuable suggestions were given in the answers received for successfully carrying on work under the short term contract system. The following pointers will apply to most places and conditions in Hawaii:

1. Always give the rate before the work is started and stay by the rate when it is too high. Use your experience and better judgment in giving a fairer rate next time.
2. "Many more jobs than are now done by short term contract could be done by this method if a contract rate book is kept in the plantation office and all details of the conditions of the job entered alongside of the job and rate. This book could then be consulted by anyone on the plantation to secure the proper rates. Several plantations now do this."

3. "Have good, honest, and conscientious field and gang lunas."

4. Give rates for the job sufficiently high to be an incentive to work hard and not rates whereby the laborer, even though he "sweats his brow off" can not make more than day wages, and thereby becomes discouraged.

5. "Regarding short term contract, I want to say I am a strong backer of this system, so much so that about 75 per cent of the work done under my supervision is handled in this way. I find it to be a great labor saver and also helps to cut down costs of cultivation."

6. "Of all short term contracts I believe a weeding contract to be the most difficult to give correctly. While other contracts, such as planting, cutting, or loading cane, may vary a few cents per ton or a dollar or so per acre, a weeding contract may be worth anywhere from $1.00 to $20.00 per acre.

"A luna can not go into a field and simply by looking at the grass say how much it is worth. A weeding rate can not be guessed at, if you expect to get the most out of your men, as they know you are only guessing and will work slowly with the idea of getting a higher rate. Only men who know the game should be allowed to give out weeding contracts, and a little extra time spent arriving at a rate that is more or less correct is time well spent and has a mighty good effect upon the men, and then they know you are not guessing.

"The way I arrive at a rate is to take one man from the gang, not the best man—just any one I happen to pick. With my watch in my hand I time him on two or three lines or more, then I take his average time per line, say it is 10 minutes. Then he will do, at this rate, 6 lines per hour. If he works 10 hours per day, he will do 60 lines. I usually take off about 10 lines to allow for level ditches. That would make 50 lines per day per man, or at the rate of about 5½ men per acre, if the lines are 30 feet. In this instance, I would offer then $7.00 per acre, with the idea of letting them "Jew" me up to $8.00, which would be about right, and they would feel that they were working at their own figure, which has a very good effect on them. A contract given out in this way seldom goes wrong."

7. "Get dependable contract bosses."

8. "For short term contracts in irrigation, it is very important to have a good water luna in the field to see that the men do not take too much water and break things up."

9. "The way I believe short term contracts can be improved is to have one experienced man in charge of all contract work. Spend enough time with the men to arrive at the correct rate, and pay them what they make. Never cut them down after you have set the rates. But the main thing is to have a good man to take charge of the work, especially one the men have confidence in and know they are going to get a square deal."

10. "While in charge of tunnel construction I have used a short term contract that worked out very well. It had been customary to give out each tunnel, regardless of its length, at a certain price per foot. The contractor, who hit easy going, made a lot of money, while the one that hit it hard and saw that he was going to lose out, usually folded his tent and disappeared, leaving us in the lurch. So I started giving a flat rate for a certain number of feet, depending upon the material they were in at the time. If it was hard material, 25 or 50 feet was

about the limit. If it was softer, such as soft dirt, I would give them up to 200 feet, but usually they were satisfied with about 100, as they were afraid of it getting hard.

"This system is a very interesting gamble and it made a big hit with them. It also protected the contractor as well as the company. If they lost, the losses were light. If they were lucky, they did not make too much. It all depended upon the run of material, and was an even break. If they hit it hard just before their contract ran out, they would work their heads off so they would not lose too much. On the other hand, if they hit it easy there was great rejoicing but no slacking up in the work."

11. "The best suggestion I could make is to put all men on their own, take them out of a gang and have good lunas with not too many men under them. About 20 men is the most a luna can handle and keep his lines straight. If a section overseer places a rate on a field and it is too high he should let it go that day, for if he should change it the labor would lose confidence in him. The men will know if the rate is too high and will take the cut the next day and be satisfied."

12. (a) "Always fix the price before men commence their task and keep them to that price no matter how much or how little they make. Price should be set by a responsible overseer.

(b) "Gangs should never be more than from twenty to thirty men.

(c) "Have a good luna:

(1) Who is capable of seeing that men make a reasonably good job;

(2) Who can demonstrate to men in a satisfactory way;

(3) Who can send the slackers of the gang about their business.

12. (d) "When commencing a new task, if men are shown what is wanted during the first hour, I have found that this is more than half the battle."

13. (a) "For weeding and hoeing, if rough work is being done, send them on day work for a while with a luna at day rates.

(b) "For cutting cane, especially with Filipinos, I got good results last year by having an expert cutter show every man the proper method of cutting and piling at the flume. If I found a rough cane cutter after that, I put him in the day work gang. We had good clean fields last year compared with previous years.

(c) "Pay enough on hoeing. If you stint them you are liable to get poor work.

(d) "Select the very best men for contractors. Men who are leaders. Don't fool around with a weakling or a man who won't dirty his clothes. It doesn't pay."

Rates Vary With Conditions

In the following tables are given some of the rates paid for various jobs. These rates are simply the amounts paid to the laborers. They do not represent the total cost to the plantation, because they do not include overhead, supervision costs, material, etc.

It must be understood at the beginning that it is absolutely impossible to fix one set of rates that will apply to all conditions throughout the Territory, or even to all fields on the same plantation. For this reason rates quoted by men on each of the four main islands are listed separately.

RATES:

JOB	OAHU	MAUI	KAUAI	HAWAII
Steam Plowing	$3.50 to $4 1st plowing. $3 to $3.50 per acre 2nd plowing.			Next year trying steam plowing by short term contract.
Tractor Plowing	$2 per acre with 60 h. p. tractor and 4-disc plow.		$3 to $4.50 1st and $2 to $4 2nd plowing.	Fordson $3 to $5 per acre.
Harrowing				
A—Tractor				$1 to $2 per acre.
B—Mules				$2 to $3 per acre.
C—Steam plow	50c per acre		35 to 60 cents per acre.	
Mouldboarding				
A—Tractors and 1 plow	$2 per acre.		$2 per acre.	
B—Tractors and 2 plows	$1.75 per acre.		$1.50 per acre.	
Mules			$3 to $4.25 per acre.	$2 to $4 per acre.
Preparing Lines				
A—Plow (1 mule and canoe plow).	75c per acre.			$1 per acre, small plow with two mules.
B—Hoes	$1.25 per acre.		½ to 1½c per line.	⅓ to ½c per line of 33 feet.
Planting				
(a) Acre		$6.50.	$10 to $12, including 1st water. $6 per acre on unirrigated land.	$4.25 to $4.50 on unirrigated land. $5 to $8 per acre, including preparing with hoes.
(b) Bag	3c to 8c per bag, depending on amt. of preparing necessary and amt. seed is lapped.			
(c) Marking watercourses			25c per acre.	

JOB	OAHU	MAUI	KAUAI	HAWAII
First Irrigation	1¼c line. 1½c line with trash panis.	1 to 1½c line with panis. 1c line no panis.	$2.50 acre no trash, $3 acre with trash.	$4.50 to $5.50 including trash, panis, and cleaning level ditches.
2nd Irrigation	¾c line	½ to ¾c line, taking two watercourses.		$2.25 per acre. $2.00 and $1.75.
3rd Irrigation	¾c line	¾c line.		$1.75 per acre.
Later Irrigation				½ to ¾c line.
Making trash panis in bundles			30c per 100 panis.	
Hoeing				
A—Light grass	¾c to 1½c line.	1 to 2c line.	$4 acre, ½ to 2c line	$3 to $4 per acre. From $6.50 per acre up.
B—Medium grass.	1½c to 2c line.	2 to 4c line.	$7 to $8 acre, 2c to 4c line.	$4 to $5 acre. $5 to $6.75.
C—Heavy grass.	2½c to 5c line.	Up to 10c line. 3 to 6c line.	$10 to $12 per acre. 4c a line and up.	$5 to $8 acre. Up to $10 acre. $7 to $8.50 acre.
Carrying Seed for Planting With Pack Saddles.	¼ to ½c per bag, depending on distance, character of land, etc.		½ to ¾c per bag.	$1 to $3 per acre, depending on nature of land, length of pack.
Cutting Seed				
A—Top	10c for 70 lb. bag.	10 to 15c bag, 135 seeds in a bag; 8 to 12c, 125 seeds.	10c per bag ahead of cutting, 8c behind; 9c including packing to cars.	8½ to 13c, depending on variety and tasseling; 70 lb. bags. $2.50 ton.
B—Body.	5c for 70 lb. bag.	4 to 7c bag of 135 seeds.	6c bag. 5c for 60 to 70 lb. bag.	
Size of bags.				25 to 35 bags per ton.

JOB	OAHU	MAUI	KAUAI	HAWAII
Digging Out Track Lines	1c per line, 3c for main lines.	1c line where track crosses furrows, 3c where track runs full length of furrows. 5c for main lines.	$3.00 per acre for all tracks.	
Palepale	1c line	$2.25 to $2.50 acre.	1c line.	$1.50 to $2.50 per acre.
Cutting Back				
A—Hoes		75c to $1.00 per acre.	$1.00 per acre on ratoon cane.	
B—Knives	$1.25 per acre.	½c line and tops put in watercourse.	$1.00 per acre on plant cane.	
Fertilizing				
I. Nitrate of Soda.				
(a) 3 bags per acre.	20c bag.		30c bag.	
(b) 4 bags per acre.	18c bag.		22c bag.	
(c) 5 bags per acre.	15c bag.			
II. High-Grade.				
(a) 3 bags per acre.		13 to 15c.		12c bag and 10c additional for each bag over 12.
(b) 4 bags per acre.		10 to 13c.		
(c) 5 bags per acre.			15c bag, including carrying in.	
(d) 6 bags per acre.	10c.		10c.	
(e) 8 bags per acre.	9c.	9 to 10c.		
(f) 10 bags per acre.	9c.			
III. Rock phosphate thrown broadcast on plowed land —5 bags per acre.			5c per bag.	
IV. Washing fertilizer bags.	20c per 100 bags.			

JOB	OAHU	MAUI	KAUAI	HAWAII
Laying Portable Track	23c per section.	6c a ton. 5c a ton on flats, 7c a ton in rocky land, 4½c in machine loaded fields.	10c per rail, 12½c for heavy rails.	
A—Putting in switches.			35c.	
B—Laying portable flume.				4c to 7c per ton of cane flumed.
C—Packing for fluming.				14 to 16c ton.
D—Putting cane in flume.				14 to 17c ton.
E—Loading flume cane in cars.				4 to 5c ton.
Small Cane	Add 4 to 6c per car and let hapaiko men pick it all up.	$1.00 per ton.	$1 to $1.30 per ton.	
Cleaning, Scraping and Painting Rails After Harvesting			32c per section.	
Hilling-Up with Mules	$6 acre for 4 times small plow and 1 time mould board.		$5 per acre running 3 times with 6″ plow and once with clean plow.	
B—"Hukilepo" after hilling-up.	1c to 1½c per line.	$3 to $4 per acre.	$2.50 to $3.50 per acre.	
Stripping Cane				$4 to $5 per acre.
Cutting Cane Tops	75c car.			
Clearing Land				
A—Heavy Lantana.			$15 to $20 per acre.	
B—Stones.				$8.50 per acre, including clearing ends of fields.

JOB	OAHU	MAUI	KAUAI	HAWAII
Digging Drain or Irrigation Ditches				
1½ ft. x 1½ ft.	2c ft.		30c cu. yd. 3c ft.	
2 ft. x 2 ft.	3c ft.	3 to 4c foot.	4 to 5c ft. 3c per ft.	2c ft. and 4c ft. in rocky land.
3 ft. x 3 ft.			8 to 10c foot.	
2½ ft. x 2½ ft.				3½ to 5½c per ft.
14 in. x 21 in.	¼ to ½c ft.			2 to 3 cents.
Cleaning Level Ditches			½c foot.	
Putting in Water Gates		Small gates 40c. Large gates 75c. Large boxes $1.25 each.	35c per gate.	
Loading Dirt on Cars	75c car.	25c yard.		
Loading Sand	30c car.		20c yd.	
Unloading Sand	15c car.		10c yard.	
Loading Rock	12c ton.	14c ton.		
Unloading				
(a) Mudpress.	37c car.	20 to 25c car on main line. 15c car dumping in irrigation ditch.	25c car.	50c ton unloading and spreading.
(b) Manure.				$1 per ton, 25c per wagon.
Unloading 320 bag cars of fertilizer into warehouses.			$3 per car.	

JOB	OAHU	MAUI	KAUAI	HAWAII
Making Fences				
(a) Single wire fence to keep cane up.	12c per post, wire included.			
(b)	7c per ft. for dipping posts, digging holes, making gates and putting up woven wire fence.			
(c) Dipping posts in creosote solution.			½c per post.	
(e) Digging post holes.		3c for 2 ft. hole, 5 to 8c in rocky land.		
Painting House (Costs figured on square feet of floor space).				
(a) By hand.	Inside 2c. Outside 2c.			
(b) By electric portable paint machine.	1c sq. ft.			
Cutting Wood				
A—General.		$1.55 cord.	$1.50 cord.	$2 to $2.50 cord.
B—Eucalyptus.	$2 per cord.	$1.65 cord and 35c for loading and hauling to main line.		
C—Plum.			$1.20.	
D—Pine.			$1.50.	
E—Koa.			$1.35.	
F—Ohia.				$4.50 cord.
Planting Trees (including digging hole and giving first irrigation).			3c each.	

JOB	OAHU	MAUI	KAUAI	HAWAII
Stone Ditches	2 stone, 60c ft. 3 stone, $1 ft.			
Cement Ditches		$2.70 ft. for 7′ x 2′ x 2′ ditch, including material.		
Laying Concrete Pipe Ditches	8c ft.			
Tunneling				
1st 100 feet.	In soft rock $2.50 per yard. In hard earth, $1.50 per yard.		In soft dirt 60c cu. yd. for 1st 100 ft. and additional 15c per yd. for each 100 ft. additional.	
Breaking Rock.	65c yd. breaking and loading on cars.		50c yard.	
Digging Cesspools				
6½ ft. x 6½ ft. and 10 to 13 ft. deep.	Soft earth $5 to $7. Rock dirt $7 to $12.			
Paper Mulching				
(a) Palepaleing.				$3 to $4 per acre.
(b) Mulching.				$3 to $3.50 per acre.
(c) Slitting.				30c to 40c per acre.
Spraying				
(a) Knapsack.				$6 to $8 per acre.
(b) Sled.				$4 to $5 per acre.
(c) Hand pump with 3 hoses.				$5 to $7 per acre.
Making Rat Torpedoes			75c per 1000.	
Dipping Rat Torpedoes			15c per 1000.	
Trapping Rats			$1 per day and 1¼c per tail extra.	

Rates for such jobs as planting on irrigated and unirrgiated plantations necessarily vary a great deal. Hoeing in two adjoining fields on the same plantation, even where the amount and the size of the weeds are practically the same, may require very different prices, because one field may be very rocky and the other free from rocks, or the soil may naturally be very hard to work on one field and very easily handled on the other. These things must be kept in mind when studying the figures quoted. But an intelligent luna, using the figures as a base, can very easily see how much and where he must vary them to meet his own particular conditions.

When two or more rates are quoted for a job under an island heading, it is because the variation in the rate paid on the different plantations, due to conditions or to dissimilar work, require considerable differences in price.

Sliding Scale Rates

An important improvement that has not been generally adopted for most short term contract jobs on the plantations is the use of the sliding scale in fixing rates. One plantation reports that it pays twelve cents a bag for throwing three or four bags of fertilizer per acre and gives a bonus of ten cents a bag for each bag over twelve that the laborer throws in a single day. This is a double incentive to the good men to work hard and earn more pay. Only the best men will profit by this arrangement, but it gives every man in the gang something to "shoot at."

This sliding scale rate is used quite generally in cutting and loading cane contracts. It can be used effectively for many more operations. Such practices really do not cost the plantations any more, because fewer men do more work and the lowering of the overhead will more than make up for the small amount extra paid to the good men as a bonus.

Harvesting Rates

Harvesting rates are not discussed here because they are more or less fixed for the different islands and different conditions by the H. S. P. A. rulings. As a general rule, four to six cents per ton more is paid for cutting unburned cane than cane with all the trash on it. Such a variety as D 1135 costs about three cents a ton more to cut than the heavier Caledonia or H 109 canes.

As mentioned previously, it is now more or less common practice to use a sliding scale in paying for cutting and loading cane. This rate is usually a monthly proposition rather than a daily one so as to take care of the variation in the quality of the cane that the men must cut and load. There is quite a difference, due to the fields, stand and weight of the cane, variety, etc., in the amount a good man can do at different times. But for cutting or loading the minimum amount per month, the man is given the minimum wage. As the amount he does increases, the pay per ton automatically increases, so that the good man not only gets the extra pay for the extra work he accomplishes, but gets paid at a higher rate per ton for his services.

Reporting the Work

Since the supervision and the setting of fair rates is such an important part of handling short term contract work, it is necessary to keep in close daily touch

with the amount of work done and the earnings per man. For this purpose some such form as the following is good for reporting work:

THE MAIKAI SUGAR COMPANY

Gang............................ Field............................ Operation............................

Bango	Lines	Bags	Feet	Rate	Earnings	Remarks
					$	
TOTAL						

Gang Luna..

Section Luna..

Date..

This is merely a sample, and may be varied to suit the conditions or requirements of the various plantations. But any such jobs as hoeing, preparing lines, irrigating, spreading fertilizer, cutting seed, cleaning ditches or roads, etc., can be reported by simply filling in the proper heading under "Operation" and the amount done per individual man on the line with his bango number, marking under "Lines, Bags, Feet, Rate, etc.," the amount he has done and the rate he reecives.

Confidence Necessary

To get the best results with the men when giving short term contracts, it has been found that it is absolutely necessary to get and hold their confidence. Among the suggestions printed earlier in this paper is one that the rate suggested to the men be somewhat lower than the overseer really feels is the fair rate so that the men may have the satisfaction of "Jewing up" the price. The man who suggested this gave some of the most valuable suggestions printed in this paper, but seems to be wrong in this one particular. When one goes into a store to buy an article, he likes to have it offered at a reasonable price, and loses confidence in the store when the clerk begins lowering his price to make the sale.

When the men learn, after a few experiences, that the overseer is just as interested as they are in fixing a fair rate, they will soon take the price he gives them without complaint. They will know that if a mistake in judgment has been

made so that they can not make a reasonable wage with increased efforts, a fair adjustment will be made.

Teach Your Men

A large majority of the men at present employed on our plantations are willing and anxious to do good work. Printed under "Suggestions for Improving Our Methods of Handling Short Term Contracts" is this statement by one overseer: "When commencing a new task, if men are shown what is wanted during the first hour, I have found that this is more than half the battle."

That is absolutely true. A good luna today is not the mythical old tyrant of the past, who "cussed and kicked" the work out of the men. He is the man who knows how to do the work well himself, and who can and does get in and *calmly* shows the men how the job is best done. A luna, with a hoe in is hand, going along the line covering up seed with long sliding scrape of his hoe on the upper edge of the furrow, can get his ideas across to the men ten times quicker and with a tenth of the effort of the man who simply stands and yells, "I told you to do it so-and-so way." Laborers respect intelligence in lunas. They appreciate friendly advice and help, but they resent unreasonable abuse from men who are either too lazy or too ignorant to *show* them how to do the job.

Short Term Contracts For School Children

During the school vacations there are always a number of children around the plantations who want to work. It is good policy to give them employment, even when the plantation could probably get along without them. If we are to hold the younger generation on the plantations we are going to have to educate them along plantation lines, teach them to think of the plantation as their future homes, make the work fairly attractive to them, and show them that there really are good opportunities for them if they can "deliver the goods." The fixing of a day rate is often difficult for these children, because there is such a great difference in their abilities, regardless of their sizes.

The short term contract is also ideal for these young school boys. Every one gets paid for just what he does. They take a much greater interest in their work and they accomplish more. It is entirely reasonable to think that a far higher per cent of them will "stick to the plantation" than if their first impressions were gained from monotonous day work, where their idea is to watch the luna and the clock rather than to see how much they can earn by improving their work.

Times change. Improvements are constantly and universally being made in modern methods. Basing our plans upon the knowledge gained through years of experience in the past and upon scientific research in the present, we have to keep up with the procession or be lost. And it does not matter whether it is labor or machinery that we are handling. The principle applies just the same.

Practical Sugar Cane Genetics*

By C. F. Poole

The object of the committee this year is to establish a common genetical basis for the solution of cane improvement problems, both in seedlings and bud selection.

Sexual Improvement of Seedlings

With the development of the sulphurous acid solution by the Experiment Station, it is now possible to work with a greater degree of certainty in our seedling propagation. For the first time, now, we are able to use good control cross-pollination and self-pollination. Indian corn, or maize, is not only a close relative of sugar cane, but the two plants resemble each other in being normally cross-pollinated. It would be to our advantage, therefore, to adapt to our own uses some of the breeding experiments in corn, especially those concerned with hybrid vigor. This can be accomplished by producing near-homozygous strains, in inbreeding several generations of seedlings of the same two parents, or self-pollinating in one variety. After several generations of such work, possibly four or five, we should have a seedling or two, the seedlings of which, when self-pollinated, give individuals of uniformity of character, but greatly reduced vigor from the parent form (Castle, p. 242). The chief advantage of this consists in affording a ready means of eliminating all but the strongest individuals (Babcock, p. 356). After this point, cross-breeding will result not only in the combination of new parental characters, but the phenomenon of increased vigor over either parent.

On many plantations there are crosses of Lahaina and H 109, as well as Lahaina and other Lahaina seedlings, such as most of the seedlings of commercial promise at present on Kauai. The Experiment Station proposes to cross-pollinate among the D 1135—Uba seedlings.

Factor Relations in Quantitative Inheritance

The main object in analyzing factor relations is to learn the manner of inheritance. This is a line of investigation that has not yet been applied in Hawaii. It would be of great value in seedling propagation to have definite information along these lines, and it might be well to consider the subject under the following heads:

1. Do any characters exhibit typical Mendelian inheritance, that is, after the second generations are the parental characters segregated in the ratio of 3-1?

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* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

2. In the first generation of a hybrid are the characters of each parent blended to form intermediate characters?

3. Are some factors linked together in the first generation while others disappear and reappear in subsequent generations?

To answer such questions we must have, first, definite knowledge of the two parents, and, second, sufficient offspring from such a cross to provide a fair measure of the range of inheritance for any particular factor.

In the accompanying table is submitted a list of twenty-five seedlings which are presumed to be natural field hybrids, with the female parent and the probable male parent indicated, showing the size of each seedling for the specific factors considered. For convenience in study, they are presented in groups of five seedlings, each group consisting of those of the same probable parents. At the end of each group the same data are presented for the two parents.

The short space of time available for the preparation of this section of the paper has made it impossible to include a large enough number of seedlings per group to furnish a fair range for any of the factors. However, those included will serve the purposes of a preliminary study and afford an opportunity for suggestion and criticism.

Measurements for the parent varieties, D 1135 and H 109, were made in the same field as the seedlings, but the Lahaina was obtained elsewhere, and in a location where the so-called "Lahaina trouble" was evident. The particular stool measured, however, seemed to have recovered a normal growth. These three parent varieties consisted of one stool each, issuing from a single-eye seed piece, whereas the seedlings were from the first field test, and, therefore, not from vegetative cuttings. This renders invalid a comparison of the number of stalks between parents and offspring.

Examining the available material, it is evident that few, if any, conclusions are warranted. However, it is interesting to note, from a comparison of the group averages:

1. There is apparently no loss in vigor in the case of self-pollination, or cross-pollination between two closely related varieties like Lahaina and H 109, such as would be expected in inbreeding.

2. It appears that H 109 as a female parent in the vicinity of the D 1135 to the windward furnishes poor seedlings.

Size Inheritance

Seedling	Circum.	Length Joint	Area of Nodes in Inches	Aver. 30 Days Growth in Inches	Leaf Ratio	No. of Stalks	Parentage (Female First)
A 11.7	4.55	4.05	18.43	8.8	19.1	16	
A 24.7	5.46	3.00	16.39	7.9	20.5	4	
A 25.7	4.14	3.82	15.81	9.0	19.4	16	D 1135 x H 109
C 6.1	3.59	2.74	9.83	6.8	22.3	12	
B 25.5	5.21	3.56	18.57	9.6	21.2	18	
Average			15.81	8.4	20.50	13.2	
D 1135	3.63	3.25	11.80	6.9	21.4	7	
H 109	4.95	3.68	18.22	7.5	18.9	5	
Average			15.01	7.2	20.15	6	
C 15.5	4.77	3.53	16.82	12.6	19.2	13	
C 20.1	4.47	3.86	17.27	9.0	17.6	16	
C 21.8	4.51	3.75	16.91	9.4	20.0	14	H 109 x Lahaina
D 3.9	4.45	3.33	14.82	9.0	21.0	14	
D 26.8	4.23	3.71	15.70	9.8	21.1	15	
Average			16.30	9.96	19.77	14.4	
H 109	4.95	3.68	18.22	7.5	18.9	5	
Lah.	4.28	2.57	11.00	6.9	24.6	5	
Average			14.61	7.2	21.75	5	
B 20.7	4.44	3.56	15.80	9.0	22.2	11	Lah. x ? (Big Rib-
B 21.2	5.32	3.53	18.78	8.9	18.5	12	bon on wind-
B 24.5	5.99	3.33	19.97	6.6	18.8	6	ward; no tassels
C 32.2	4.54	3.47	15.77	8.3	19.0	14	at time of col-
B 23.1	4.19	4.18	17.52	10.8	21.1	11	lection.)
Average			17.57	8.72	19.92	10.8	
Lah.	4.28	2.57	11.00	6.9	24.6	5	
C 12.1	4.85	3.11	15.09	8.0	22.4	9	
D 24.8	4.97	3.74	18.59	9.0	16.5	12	
D 25.5	5.94	3.25	19.30	9.0	21.7	12	Lah. x H 109
D 30.8	4.31	3.03	13.07	7.2	22.0	19	
C 13.7	4.62	3.13	14.48	7.6	20.0	9	
Average			16.11	8.16	20.52	12.2	
Lah.	4.28	2.57	11.00	6.9	24.6	5	
H 109	4.95	3.68	18.22	7.5	18.9	5	
Average			14.61	7.2	21.75	5	
A 22.1	4.14	2.62	10.86	5.5	19.4	26	
A 13.1	3.46	3.70	12.80	7.1	21.7	23	
A 13.2	4.31	3.39	14.62	8.0	20.2	10	H 109 x D 1135
B 19.2	4.40	1.85	8.14	5.0	17.3	6	
D 2.2	2.94	2.79	8.21	6.9	17.5	12	
Average			10.93	6.5	19.22	15.4	
H 109	4.95	3.68	18.22	7.5	18.9	5	
D 1135	3.63	3.25	11.80	6.9	21.4	7	
Average			15.01	7.2	20.15	6	

3. From the leaf ratio of the first group seedlings, it might be concluded that the narrower D 1135 leaf is transmitted to the majority of the seedlings. This likewise might be the case in the fourth group, where Lahaina is the maternal parent.

4. Providing cross-pollination, as indicated for each group, has been effected, it seems more probable that a blended type of inheritance is transmitted, although it must be admitted that five seedlings per group are insufficient for such an assumption.

One point that is made clear from this exercise is that all our parent and seedling varieties are too heterozygous to furnish definite information along these lines. It is hoped that this line of investigation will be followed up in the near future, and that homozygous canes will be bred and used for the purpose. According to Jennings and Fish, as quoted by Castle, homozygosity is approached by inbreeding three times as rapidly by self-fertilizing as by mating brothers and sisters. It is also possible to obtain homozygosity immediately, or never.

A Sexual Improvement, Mutations, Bud Selection, Etc.

(a) *Mutations:* It is well known that sugar cane is subject to mutations. These mutations may be the result of a recombination of ancestral characters in the body cells of hybridized varieties, or they may be factor mutations, new combinations in the germ cells. At any rate, we know they are heritable, and have given rise to some of our most important varieties of cane, as, for instance, Yellow Caledonia.

In the following table are shown the color mutations that have arisen within only three generations in a single stool of three stalks of Big Ribbon. In 1924, there were three stools, two of which remained Big Ribbon, and were not spread further, the other stool giving rise to a mutating stalk, consisting of six stalks of Big Ribbon and one stalk which started as Big Ribbon and changed to Black Tanna. Three seeds of each kind were taken from this one stalk. At the same time as Black Tanna was forming in this one stalk, there seemed to be a tendency in a few of the other stalks to lose their stripes. And in the following generation five of those stools gave rise to one stalk each of Yellow Caledonia. (B. R. is Big Ribbon, B. T. is Black Tanna, Y. C. is Yellow Caledonia, and M. is mixed joints on one stalk):

	1925 B. R.	B. T.	Y. C.	M.	1924 B. R.	B. T.	Y. C.	M.	1923 B. R.	B. T.	Y. C.	M.
(a)	0	1	0	0	0	0	0	1				
(b)	0	2	0	0	(Black Tanna)							
(c)	0	1	0	0								
(d)	1	1	0	0								
(e)	0	3	0	0	(Big Ribbon)							
(f)	0	3	0	0					3	0	0	0
(g)	3	0	1	0								
(h)	1	0	1	0								
(i)	1	0	1	1								
(j)	2	0	1	0								
(k)	2	0	1	0								
(l)	2	0	0	0	6	0	0	0				
(m)	3	0	0	0								
(n)	3	0	0	0								
(o)	1	0	0	0								
(p)	5	0	0	0								
(q)	5	0	0	1								
		Not Spread			8	0	0	0				
		" "			9	0	0	0				

Several other pedigrees of a like nature in Big Ribbon suggest that once a stalk of Black Tanna or Yellow Caledonia has been formed, there is a strong tendency, which has not yet been observed to fail, to maintain the new mutation.

(b) *Pure Lines:* Twenty-five progenies of H 109 cane have been under observation for three generations. In 1923 (the second year), these twenty-five progenies were divided into two sections, Section 4 containing all stools of five or more stalks, and Section 5 the smallest stools remaining. In 1924, a second selection was made within these two sections on the basis of the sub-progeny performance, in which only one-quarter of the sub-progenies were selected. This gives us different mean values for: (X) the average of the sub-progenies constituting the main progeny, (A) the average of only those sub-progenies qualifying for planting in the 1924 project, conforming again to the idea of selecting plus variants, but making discards of entire sub-progenies and not individual stools.

As will be seen from the following table, material improvement resulted from this second selection in the: (1) mean stalk-stool coefficient, M, (2) standard deviation, σ, and (3) coefficient of variability, CV.

	1922 M	σ	CV	1923 M	σ	CV	1924 M	σ	CV
Sec. 4	4.364	.213	4.87	X—5.06	.168	3.32	4.88	.492	10.07
				A—5.53	.148	2.68			
				Sub—5.56	.332	5.96	4.80	.637	13.26
Sec. 5	4.365	.284	6.49	X—5.33	.310	5.82	4.55	.628	13.75
				A—6.12	.230	3.76			
				Sub.—6.16	.413	6.70	4.66	.717	15.39

In each generation, both 1923 and 1924, ~~there~~ has been a failure of the selection of plus variants to improve the population. In fact, in 1923, it appears that

Section 5 is superior to Section 4, giving a negative effect for plus selection; however, in 1924, the relative yields of the two sections are again reversed. The line "Sub-" refers to data obtained studying the correlation among the sub-progenies, while X and A refer to the average of whole progenies.

The coefficients of correlation between the S-S coefficients for the three generations here recorded are quite erratic. For 1922-1923, they are $0.2779 \mp .1671$ for Section 4, and $0.3138 \pm .1285$ for Section 5. Subsequent correlations are inconsistent, due, no doubt, to the small number of progenies per section. However, they do not affect the parallel behavior between this vegetatively propagated material and Johannsen studies in "pure lines."

This is more strikingly brought out by tabulating the values of these two sections according to ranks, as determined by the stalk-stool coefficient.

After three generations these twenty-five progenies had been condensed by selection to fourteen progenies in Section 4. and twenty-three progenies in Section 5, and the fourteen progenies of Section 4 were brother progenies to fourteen of the Section 5 progenies. In Sections 4 and 5 there were two progenies each which showed superior performance for all three generations, and, very significantly, the two progenies of Section 4 were the brother progenies to the two progenies of Section 5, Nos. 33 and 38. Also, it appears that Nos. 9 and 20 have been consistently poor.

In the following table, the progenies will be designated by the original field number of 1922. The numbers of the table under the three main columns, 1922, 1923 and 1924, show the ranks, and the fourth column shows the numerical total of the ranks:

RANK BY STALKS-STOOL COEFFICIENT

	Section 5				Section 4			
No.	1922	1923	1924		1922	1923	1924	
1	1	11	20	32				
2	2	12	22	36				
3	15	18	21	54				
5	16	6	13	35				
7	12	9	15	36				
9	22	13	23	58				
12	7	16	17	40				
15	17	1	14	32				
18	23	4	12	39				
20	18	32	19	59	11	13	10	34
22	13	20	16	49	9	8	4	21
26	4	23	2	29	2	14	6	22
27	19	8	7	34	12	9	2	23
29	20	14	10	44	13	10	7	30
33	6	3	5	14	4	1	1	6
35	11	2	11	24	8	4	8	20
36	21	5	4	30	14	6	5	25
37	8	21	3	32	5	12	12	29
38	3	7	1	11	1	2	3	6
42	5	15	6	26	3	3	14	20
45	10	10	18	38	7	11	9	27
47	9	19	8	36	6	5	11	22
49	14	17	9	40	10	7	13	30

Theoretically, a new seedling, such as H 109, behaves like a "pure line" when it is propagated by vegetative cuttings. However, a mutation within this seedling would establish another pure line, and if the seedling is given to many mutations, we should, in a short time, have a mixed population. In view of the above results, and of the further fact that H 109 throws color mutations, which are very evident, we may safely assume that we have such a mixed population in these two sections of H 109.

Using Babcock as an authority: "There is now abundant evidence that genetic diversity is expressed in minute morphological and physiological differences, and hence that mutations produce those small inheritable differences logically required for the explanation of adaptation through natural selection."

(c) *Bud Selection:* It is now about five years since the problem of bud selection was first applied to sugar cane in Hawaii, and from the number of projects now in process there should be ample mathematical evidence of its success or failure. However, in the absence of any such data being published, it is the purpose of the committee to present some figures, and outline a few standard biometrical methods of study. It is also our hope to establish a common basis of handling selection problems on the individual plantations.

In analyzing the situation up to the present, there are certain fundamental questions that must be considered: first, are we making any progress? second, what methods of selection are most adequate?

In dealing with the first question of progress, it is important that we use standard methods applicable to the particular work being done. Are we using a method of mass selection, or is it a pedigree system? In mass selection, we take a population of which we know the average yield and attempt to improve this average by eliminating poor material. This is almost sure to effect a favorable result, for the evidence disclosed by pure line investigation, and our knowledge of poor mutations, shows that some inherently inferior individuals can be recognized at sight. But we cannot distinguish superior mutations from the heavier type of chance variations that depend on environment, and what improvement is made is sure to be small and to require a long period of time. On the other hand, with pedigree culture we segregate the individual progenies and keep careful and complete record of the performances of it and of its sub-progenies for several generations. This enables us to know the comparative quality of each progeny. It would be fatal to the system if any eliminations were made of stalks, stools, or sub-progenies.

By the latter method we can distinguish a superior yielding progeny in a comparatively short time, whereas in the former method we must always keep a mixed population in which all the mediocre material can never be identified and discarded.

From evidence thus far available it appears that variability in yield is more evident than constancy. Only a small percentage of the progenies in the upper distribution will remain constant for two successive years, and a smaller percentage still for three successive years.

The only effective method of measuring the strength of relationship between the progeny performances from year to year is the coefficient of correlation. In no other way can we tell if there are any constant mutations.

In the following table, the correlation coefficients for eight sections of cane, comprising the three standard varieties, together with the probable errors, are given. Recently, some of these coefficients have been rechecked, and although some errors were found, the results are substantially as here recorded; as time is short, a recalculation is immaterial. The standard of measure applied to each progeny, called, for short, the stalk-stool coefficient, is obtained by use of the following formula: $6.67 \log \sqrt{}$ a b, in which *a* is the stalks per foot, and *b* is the stalks per stool. Use of the formula is simplified with a chart having logarithmic scales to represent *a* and *b* parallel to each other and 8 inches apart, while the coefficient is read on an inch scale parallel to and two-thirds the distance from *a* and one-third the distance from *b*, as illustrated in the annual report on bud selection for 1924. By correlating the stalk-stool coefficients for two successive years, the coefficient of correlation is obtained.

Section	Variety	N	r	e	$\frac{1}{e^2}$	$\frac{r}{e^2}$
I	H109	104	—0.0286	0.0661		
II	H109	79	0.5405	0.0538		
III	D1135	91	0.2881	0.0648		
V	Cal	32	0.4055	0.0994		
VI	H109	39	0.1487	0.1053		
VII	H109	107	0.4035	0.0546		
VIII	Cal	110	0.2831	0.0596		
X	H109	53	—0.0805	0.0921		
		615	+0.2926	±0.024	1738.86	508.84

Leaving out the minus correlations we have:

	+0.3770	±0.0268	1392.08	524.88

From this table it is readily seen that five out of eight of these sections show a pronounced correlation, while two of these sections have slight minus correlations, an abnormal, though sometimes found case. Therefore, if we omit these two latter sections, particularly in view of the fact that their consecutive environments are very extreme (an unfair test), we have a correlation coefficient for six sections, comprising 458 progenies, of 0.3770 ± 0.0268. In order to establish the presence of correlation, the original coefficient of 0.2926 ∓ 0.0240 is amply sufficient, and leaves no room for doubt.

Coming, now, to the second question, that of reliable and adequate methods of selection, nothing is to be gained by eliminations either of poor stools or poor progenies until we reach a stage where we have a definite identification of superior and inferior progenies, which I should say is at least three generations. In the language of pure lines, these two classes of progenies would constitute progressing and regressing mutations, respectively.

As for the methods themselves, it is desirable to have a criterion of identification that measures both the heredity, and as much as possible of the environment. In theory, at least, these two requirements are partially satisfied by use of the stalk-stool formula referred to above, modified as follows: 6.67 log $\sqrt{}$ a b plus 1/X times mortality %, multiplied by the circumference of stalks, in which x is the coefficient of regression of mortality, obtained as the final step in *multiple correlation.*

The use of weights as a measure of quality or selection, would be very satisfactory providing we had (1) a uniform environment, (2) perfect germination, and (3) a sufficient area of each progeny to minimize errors. However, these three conditions are impossible to satisfy in the early stages, so long as we are using (a) single-eye seed, which is necessary for pedigree cultures, (b) planting in soils like the majority of our Hawaiian soils that vary in quality over very short distances of ground, and (c) have to make our selection hastily from large numbers of progenies.

Discussing the merits and demerits of this method of measurement, it would be well to go into detail. Stalks per foot, stalks per stool, and circumference of stalks, are measures of volume, and certainly weight of cane is a heritable factor, as already proved by correlation. For some time past, it has been thought that the percentage of shoots dying between the time of germination and stalk development has been correlated with the yield.

The percentage of mortality was assumed to be similar to a percentage that would be obtained by dividing the difference between the stalk-stool coefficients for October and January by the stalk-stool coefficients for October. This gives us an algebraic mortality percentage, and for the 615 progenies mentioned above, the correlation coefficient for 1924 is 0.6285 ∓ 0.0168.

The next step was to find if any correlation existed between the algebraic mortality percentages for the two consecutive years. The correlation coefficient in this case was found to be practically zero.

It was then assumed that percentage of mortality furnished an index of environment. We may, therefore, measure and eliminate this influence and have a better idea of the quality of the progenies. Accordingly, multiple correlation as used by Yule in *An Introduction to the Theory of Statistics* was employed, using the four factors: X_1 S-S coef. for 1923; X_2 S-S coef. for 1924; X_3 mortality percentage for 1923; and X_4 mortality percentage for 1924. By this method we obtain the regression coefficients for each of these four factors, and that for X_4 shows the influence exerted on X_2, as in the following example. In a section of 110 progenies of Yellow Caledonia we obtain the formula:

$$X_2=1.703+0.770x_1-0.003x_3-0.035x_4$$

In this section the significant figure is $-0.035x_4$, but for five sections it is -0.047. This, then, means that if the S-S coef. of 1924 is increased by .05 (or 1/20) we have our desired correction.

Therefore, we are using the new formula: $y+X4/20$, in which y is the old S-S coef. and X4 is the mortality percentage for the same year. The test of

this formula, which has only recently been developed, lies in the improvement that will be made in simple correlation.

Up to the present time, improvement has been obtained in three cases, and losses in two cases.

The chief limitation of this method of measuring pedigree cultures lies in the absolute necessity for accuracy in field measurements.

The Adaptation of Hawaiian Seedlings*

By Y. Kutsunai

In a general way, the districts and plantations to which our seedlings are adapted are those with environments similar to the growing conditions under which the parent canes used in our seedling work thrive.

The present sugar cane belt can be roughly divided into four zones. The lowest zone, which has the warmest climate, is planted with H 109. There are indications that seedlings of Lahaina and H 109 are particularly suitable for this division. This may be called the H 109 zone, for convenience.

The next is a little cooler than the H 109, and may be termed the Yellow Caledonia zone from the predominating variety here grown. The seedlings of Yellow Caledonia are being raised with the intention of supplying better varieties to take the place of the parent.

The D 1135 zone follows the Yellow Caledonia. A large number of seedlings of D 1135 have been raised, but none has yet been found to compete successfully with the parent. The failure is perhaps due to the fact that D 1135 has a strong tendency to self-fertilization and produces rather weak seedlings as the result of inbreeding.

The highest, and consequently the coolest, portion of the sugar cane belt may be termed the Tip zone. Formerly this zone was thought to be the most difficult one to supply with seedlings. However, in 1917, Tip canes, and, in 1923, Uba cane, were introduced into the seedling work with the result that many promising varieties for this coolest area have sprung up.

Thus far, sugar cane breeding and the subsequent selection of seedlings has been confined to the established sugar cane belt. If the present sugar cane boundary is to be moved beyond the upper limits of the Tip zone, it will become necessary to carry the seedling work to this new area. It may be advisable to import from foreign countries new hardy varieties of cane to be used as parents, since among our present varieties, D 117, Badila, H 146, H 227, H 456, H 468, Striped Mexican, native varieties, and new Hawaiian seedlings, none seem to be suited as parents for canes to be grown at very high elevations.

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

In addition to the prevailing average annual temperature, as above referred to, there are many other factors affecting the adaptability of Hawaiian seedlings. Among these factors may be mentioned rainfall, wind, type of soil, diseases of sugar cane, insect enemies, rats, weeds, mill equipment, amount of irrigation water, agricultural practice, prejudice, etc.

Rainfall

Many seedlings that have appeared promising under irrigated conditions cannot be successfully handled in a rainy region of equal temperature. The effect of heavy rainfall on non-stripping seedlings and lodging seedlings is obviously detrimental, and rain also seems to induce differences in soil and humidity of air. Yellow Caledonia is almost an ideal cane in the rainy district. It is erect, self-stripping, and eye spot resistant. Its seedlings are naturally looked upon with much interest for the Hilo coast.

Wind

This Territory is seldom visited by strong winds, which, consequently, are not generally considered as a factor affecting the adaptability of Hawaiian seedlings. Honokaa No. 1 is the first to be reported as a good cane in windy places, because it seems to be less torn by strong winds than any other variety.

Soils

There are many types of soil ranging from the neutral soil of the coastal plains to the acid soil of the higher rainy belt. Some are wanting in phosphoric acid, and others are in need of potash. However, varied as they are, the soils have not so far been considered very much as factors to be reckoned with in seedling distribution. Although they have important bearings on varietal adaptability, they are usually considered in the question of fertilizers.

Diseases

Such diseases as root rot, eye spot, and mosaic have rightly played an important part in deciding seedling distribution. In the case of root rot, a Hawaiian-grown seedling, H 109, has not only solved the problem but also increased the sugar yields, so that the variety is now planted irrespective of this disease. The eye spot situation is being worked out with such seedlings as H 5965 and H 8965. Mosaic disease, which hits the Tip canes very severely, is being met with Tip seedlings and Uba crosses, particularly U. D. 1.

Insects and Rodents

The control of damage due to insects and rodents through seedling work has not progressed far enough for discussion.

Weeds

Weeds, especially in the wet districts, have been a matter of great importance in the minds of cane breeders. Although no seedling has been evolved as yet to meet weedy conditions, it is hoped a variety may be found which will grow rapidly enough to shade in the weeds, thus cutting down on cultivation expenses.

Milling Quality

A certain type of seedling, although fair in sugar producing power, cannot be satisfactorily handled at the mill because of the pulpy nature of its bagasse. As an example we have H 468.

Irrigation Water

The amount of available irrigation water often influences the adaptation of our seedlings. H 5001 and XY are reported doing well on plantations which feel the shortage of irrigation water. U. D. 58 has grown to respectable size on dry spots where H 109 had previously failed for lack of water.

Agricultural Practice

Agricultural practice, particularly the amount of fertilizer applied, affects the adaptability of seedlings. For instance, under very low fertilization D 1135 outyields H 109, but when an adequate amount is used, H 109 not only outyields but gives greater profit than D 1135.

Prejudice

Prejudice sometimes handicaps a good seedling. A head overseer once remarked that he would not plant D 1135 any more because his harvesting force would not handle a crop of that variety. Although labor is an important item to consider, such an attitude is not in accord with progressive management.

Theoretically speaking, Hawaiian seedlings will eventually cover every district, field, knoll, and valley of our cane belt. There is a difference in the attitude of the cane breeder of the past and the present day in reaching this goal.

The older cane breeder produced seedlings without accurate knowledge of hereditary characters of the parental varieties. Since only a small proportion of the total number of seedlings grown in a year could be thoroughly tested on each plantation, the odds were all against a variety finding the environment to which it was especially adapted.

The present day cane breeder starts with a district, a plantation, or a locality which has a set of given conditions, and he tries to produce seedlings to suit the objective area. It is necessary in this case to study the hereditary characters of the breeding stock so as to impart to the seedlings the characters that are essential for successful growth under the given conditions.

In a study of the inheritance characters of sugar cane varieties, it seems to be important to recognize that some of the dominant and some of the recessive characters of a parental variety are transmitted in dominant form in the immediate seedlings, while some of the characters which remain recessive in the parent and the immediate seedlings, become dominant in the later seedlings. D 1135 gives occasional seedlings without eyes. H 20, a seedling of D 1135, sometimes stops developing eyes. Out of 350 seedlings of H 20, about 120 did not develop eyes on the upper parts of the sticks. Another case is seen in the seedlings of H 456 which is a seedling of H 240. Among about 2000 seedlings of this, nearly 33 per cent grew with bound-up leaves. Queer characters such as these are rare among the standard varieties, but they occasionally come to light through seedlings.

The standard varieties of today appear to be canes with good dominant characters. They, however, may possess undesirable characters that are now recessive.

Characters that are usually transmitted by the parental canes follow:

Parent	*Characters Usually Transmitted*
D 1135	Slow growth, occasional eyelessness, poor juice, adaptability to cool climate, small sticks, good ratooning power.
Lahaina	High sucrose content, poor ratooning quality, adaptability to warm field, large sticks.
H 109	Rapid growth, high sucrose content, adaptability to warm locality.
Tip canes	Adaptability to cool climate, small size stick, good ratooning power, poor juice.
Uba	Small sticks, adaptability to cold climate, poor juice, long joints, good ratooning power, rapid growth.
Striped Mexican	Large sticks, fair juice, poor ratooning quality, rapid growth, medium length joints.
Badila	Slow growth, high sucrose content, soft tissue, large sticks, short joints.
Y. C.	Large sticks, medium length joints, good growth, other characters are unknown as yet.

This list is based on impressions and is very far from complete. It is meant to be a beginning in the study of sugar cane heredity.

Inbreeding has been resorted to for the purpose of obtaining very accurate data on the hereditable characters of standard varieties generally used in seedling work here. To date, most of the selfed seedlings that have been obtained are weak and cannot stand the field conditions. Interesting examples of this nature are Badila and Lahaina selfs. Badila selfs resemble the parent variety very much except in their weak growth. These have since all died out. A Lahaina self was obtained by an early worker, but it also died. D 1135 and H 109 produce inbred seedlings. Although they survive the field conditions, they are usually weak growers.

H 1801 is one of the exceptions to this generalization. Its selfed seedlings appear to be just as vigorous as the parent.

In spite of this defect, inbreeding is perhaps the most accurate method for studying heredity, and it is hoped that in time this procedure will not only accumulate sufficient data, but will also obtain true-breeding seedlings with economic characters. Through these it may become possible to create by judicious crossing a super cane with high sugar-yielding power, high degree of disease resistance, good adaptability to given conditions, and low cost of production.

In conclusion it should be stated that seedling work is still in its infancy and needs the assistance of everybody concerned.

Fire Protection for Sugar Mills*

By Bernard Froiseth

For a great many years the fire insurance companies did not consider that it would be better business to encourage the assured to improve their property from a fire insurance standpoint, believing that their business was merely to collect premiums and distribute losses. However, the companies in recent years have changed their attitude in this regard and now encourage the assured to practice fire prevention and protection, and they maintain many organizations which make fire prevention inspections.

Sugar mills should be safeguarded in every possible way against loss by fire, and the insurance companies recognize effective protection afforded a plant by substantial credits in the rate of insurance.

Attention is called to the fact that a sugar mill may be fully covered by insurance at the time of a fire, but that the owners might suffer severe consequential losses over and above the amount of insurance that they might collect. Such uninsured losses might occur from interruption of business and also from their inability to grind the crop of growing cane.

The principal fire hazards of a sugar mill are in the boiler room, electrical installation, and steam pipes, and these hazards shall be commented on briefly before going into the matter of fire protection and prevention.

Boiler Rooms

The hazards of boiler installation come chiefly from explosion, from overheating of chimneys or stacks, with consequent setting fire to buildings; from ignition of floors, partitions, or other woodwork near by, and in connection with fuels such as oil, coal, wood, bagasse and sweepings.

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The greatest safety for any boiler installation is secured with a detached building, preferably incombustible. When it adjoins a sugar mill or warehouse, the boiler room should preferably be of fire-resistive construction, cut off with standard fire doors. If boilers are located in the mill building, the floor construction over them should be incombustible, there should be ample clearance, and neither combustible finish floor nor combustible storage kept immediately over the boiler room, if there is the least possibility of transmitted heat producing a dangerous temperature. Concrete or tile construction holds and transmits long-continued heat to a dangerous degree.

Roughly speaking, any boiler or heating device so installed that it heats surrounding wood or other inflammable material to a temperature of 150° F., or slightly more, and for a considerable period of time, is likely to cause a fire. It is astonishing to observe under what apparently safe conditions it is possible for long continued low temperatures to cause a fire.

The hazard from bagasse in the boiler room cannot be overestimated. The recent fire in the mill of the Oahu Sugar Company clearly demonstrated the fact that bagasse is subject to spontaneous combustion. The bagasse and cane dust which settle on frame, walls and roof of sections of a mill building are very combustible and constitute a menace to a plant if it is allowed to accumulate.

Electrical Fire Causes

The fundamental causes of electrical fires are arcs and overheating. The separation of conductors or parts of different potential and the design of equipment to carry safely ordinary loads and even overloads, coupled with automatic protection (fuses or circuit breakers) to open circuits if overloads become severe enough to become dangerous, enter into the design of all electrical equipment. This should be actively borne in mind in considering electrical fire hazards.

Generators have substantially the same fire hazards as motors. Disastrous fires have occurred because crane blocks have come in contact with generator connections.

Switchboards of the modern type contain little fire hazard.

Switches are dangerous largely because of poor contacts and connections causing arcs or heating, and because, if exposed and struck by metal, violent short circuits may result.

Oil switches have proved to be a very definite fire cause. The hazard lies chiefly in the oil switch rupturing under heavy overload, as from short circuits on lines, burning oil being scattered and fire spread thereby. Not only have incombustible buildings been destroyed by such fires, but the life hazard has also proved to be a considerable one.

Transformers containing oil for insulating and cooling purposes have caused some exceedingly severe fires in industrial plants.

Fuses and circuit breakers are the safety valves of electrical systems. They are often omitted and frequently abused. Circuit breakers are commonly set unnecessarily high. Fuses are too large, cartridge fuses are refilled or bridged with fuse wire of too high carrying capacity, and occasionally copper wire will

be found in place of fuses. For reasons of safety, economy and convenience, cartridge fuses properly designed should be used generally.

Temporary wiring, even if admitted dangerous in the first place, very frequently becomes permanent. Even temporary wiring should be safely installed and all dead wiring promptly removed so that it will not be connected up after disuse has permitted deterioration.

"Flash Fires"

On the mainland they have had numerous "flash fires" in sugar warehouses, caused by fibrous matter from sugar bags spreading itself on the floor—fire being occasioned by friction from the iron wheels of trucks and also from nails in the shoes of workmen. This hazard is much greater where floor is concrete than on a wood floor.

Fire Prevention

Fire prevention is fire protection. Fire prevention is a very important matter, and the old adage might be changed to read "An ounce of fire prevention is worth more than several hose streams." It is easier to guard against a fire than to extinguish it after it has once been started. Good housekeeping should be emphasized; also careful guarding of hazardous operations. If fires can be prevented from being started, naturally the fire extinguishing equipment will not be called upon.

Fire Protection

It must be borne in mind that private fire protection at the best is first aid only. A private fire department cannot be expected to cope with a serious fire; for that reason all equipment must be kept in first-class condition in order to extinguish a fire at the beginning or prevent its spreading. The protection system should be inspected regularly, beginning at the water supply and following through the supply mains, hydrants and hose, making certain that everything is as it should be. All equipment should be examined and tested. Inside protection should be carefully gone over, not only to see that it is in perfect working condition, but it should be readily accessible and distributed according to the type that is most effective for extinguishing the kind of fire that may occur.

Outside Fire Protection

Next in importance to an adequate water supply is an adequate distributing system. Such a system should be able:

1st: To deliver the desired amount of water at all important points without serious pipe friction. Keeping within a 25-pound friction allowance is good practice.

2nd: To permit concentrating all available water at important points with hose lines not over 150 feet long. This usually calls for a fairly complete covering of the plant with the piping system.

It is vitally important that absolute separation be secured as far as fire and domestic piping is concerned, for the following reasons:

(A) Domestic piping is frequently not so heavy or so well installed as fire mains, with subsequent breaks or blowouts when fire pressure is applied.

(B) Domestic connections in buildings may be broken by fire and the system bled. Safely located control valves are seldom installed in combined systems. Also, the amount of high pressure water available is limited, as a rule.

(C) Changes in domestic piping may interrupt fire service frequently in the course of a year.

A liberal number of hydrants makes for economy and efficiency. A hydrant costs only two to three times as much as a length of hose, and the depreciation on hydrants is far less than on hose. Friction in long lines of hose is a serious matter while friction in a hydrant is almost nothing by contrast. Sufficient hydrants should be installed so that 150 feet of hose, from the two nearest hydrants, will reach any fire in the central section of a plant.

If located too close to buildings, it may not be possible to reach the hydrants at the time of a fire, or they may have to be abandoned with the possibility of crippling the entire water system. Hydrants should not be closer than 50 feet from buildings of ordinary height. They should be so located that they will be out of roadways, railroad tracks, and, if possible, out of line of future buildings.

Interior Fire Extinguishing Apparatus

Valuable fire protection may be secured from inside standpipes and hose, which also have value for protection against exposure as well as for interior fires.

Four things are necessary: A supply of water; installation of pipes, valves and hose; constant maintenance; and persons available who have the knowledge and inclination to make prompt use of such facilities.

Fire plugs for inside service should be at least 1½ inches inside diameter, and so distributed throughout the building that, with 50 feet of hose at fire plugs, at least one good hose stream can be directed on all parts of the interior of the building.

Chemical extinguishers are required for inside protection, both with and without a standpipe system. These are thoroughly standardized throughout the United States, and furnish in incipient fires a small jet of water under high pressure, reaching a point of from 30 to 40 feet from the operator, and lasting, if continued in use, for about one minute. The rules of the fire marshal of Hawaii require one of these extinguishers for each 2500 feet of floor area. Extinguishers should be hung from hooks with tops about five feet from floor level. They are readily upset and partly or entirely discharge if resting on floors or shelves. Annual discharging, cleaning and recharging is recommended, partly to insure the operation of the extinguishers and partly to give employees and others an opportunity to see them used.

The Watchman

The watchman should be the most important link in a private fire prevention and protective system, but usually is not for the reason that he has not the proper qualifications. While a sugar mill is in operation, the premises are in charge of men of intelligence and ability. When a mill is not in operation, and principally at night, when the most fires occur, the premises are left in charge of the watchman, who, therefore, should be a man physically and mentally sound, alert, intelligent, and of the best morals. He should possess good sight, hearing and a keen sense of smell, all of which are valuable in the detection of fire. He should not be chosen for the job until he has been employed in other positions about the premises long enough to become acquainted. He must be familiar with the location and operation of the fire equipment, must be able to recognize fire hazards and should be given to understand that his is a position of responsibility that calls for something more than a clock puncher. A clock record that shows perfect punctuality shows the watchman thinks his only duty is to punch the clock at the proper time.

It has been gratifying that the construction of the sugar mills in Hawaii has improved materially during the past few years. Many fire hazards have been eliminated, and a considerable amount of fire protection provided. The high standards maintained by our sugar industry, largely through the channel of the Hawaiian Sugar Planters' Association, should also be applied to fire prevention and fire protection.

Ditches and Ditch Lining in Connection With Sugar Cane Irrigation in Hawaii*

By J. H. Foss

In Hawaii, not only the main watercourses in the fields are called ditches, as is the custom in other places, but main supply canals, whether open channels or tunnels, are spoken of as ditches. These supply ditches usually convey water from the rough, rainy side of the island to the drier, less rugged side, which is more suitable for sugar cane growing. With few exceptions, the water is taken directly from the streams crossed, without the use of reservoirs. The rainfall is not seasonal in Hawaii, but somewhat continuous throughout the year. This fits in well with the sugar cane irrigation, which is also carried on throughout the entire year in most localities. The lengths of the streams are comparatively short; consequently their flows are flashy, responding readily to heavy, tropical showers.

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Although most of the irrigation is dependent upon this gravity supply, there are a number of localities in which pumping is resorted to to supplement gravity supply, so as to make it possible to carry on irrigation during droughts, which occasionally occur for several weeks, and sometimes even months, at a time. There are a few places that depend entirely upon pump water for irrigation supply.

Early Irrigation Projects

The first sugar cane irrigation project of any importance in the Hawaiian Islands was built on East Maui under the direction of H. P. Baldwin, in 1876 and 1877. Immediately following this, Claus Spreckels built a similar system on East Maui. In the course of time, similar projects on Maui and other islands were undertaken, especially so after the annexation of the islands by the United States.

The value of water in sugar cane irrigation obviously depends upon the profit from the resulting sugar yield. There has been an average yield of one ton of sugar for every million gallons of water delivered to the Hawaiian Commercial and Sugar Company's and Maui Agricultural Company's plantations. This statement requires further explanation: Independent water measurements and the findings of Maxwell at the Experiment Station, indicate that only about half of this water has reached the cane. The other half is probably lost in reservoirs and service ditches. Furthermore, the resulting yield from a given quantity of water depends upon the season of the year during which the water was applied. Water applied in August may produce twice the sugar yield as an equal quantity of water applied in January. This condition makes the irrigation problem acute in the many localities where two crops are being irrigated in the summer season (the growing and the maturing crops). The demand is thus greatly intensified during this season; and supply and demand play a very important factor in the value of water. This is especially true when considering an additional supply. Additional water has great value when there is a great demand for it, but has little value when there is no demand for it. It may pay to line a ditch which carries the normal dry weather flow, and thereby add to the continuous flow a quantity of water equal to the seepage losses which have been prevented. On the other hand, it may not pay to line a ditch that carries storm water only, because this procedure would merely increase the total flow at times when little use could be made of the additional quantity. Ditch lining is, to a great extent, a problem in marginal return, the profit on the resulting additional yield.

The Economic Factor in Ditch Lining

The cost of conveying water from place to place in Hawaii, usually from streams to the fields or service reservoirs, comprises not only interest on investment, maintenance, depreciation, operation, cost, taxes, etc., but also the value of water lost in seepage and leakage during transit. Looking at it in this way, it becomes a problem of balancing the value of water annually lost against interest charges on the cost of lining.

The economic capacity of the ditch depends upon the quantity of water available and the demand for that water when it is available. If a ditch having a gravity supply were built too large, the value of the additional water that it is capable of carrying over and above a ditch of the proper size, will not warrant the difference in cost between the two ditches. Only occasionally is there sufficient quantity of available water to make use of this additional capacity, and when that occasion arises, there is a probability that there will be only a slight demand for this additional quantity, because at such times the demand is capable of being filled from many other sources. Now, go to the other extreme: An undersized ditch is one in which the value of the additional water which a proper sized ditch can carry will warrant the difference in cost between the proper sized and undersized ditches. An over or undersized ditch may represent a tremendous money loss.

It is therefore highly advisable to make a study of the quantity of water available, the demand for water, and to what extent these two are synchronous. The important work which is being carried on by the Division of Hydrography of U. S. G. S. in these islands, is furnishing us with a continuous record of the flow in all of our important streams. It can be assumed, with some degree of certainty, that the average flow conditions of the past several years (say twenty), will be repeated in the next several years. The early ditch work on the islands made it quite necessary that stream flow data be obtained by the concerns undertaking the project, which usually extended over only a short period of time just previous to undertaking the project. There always existed the possibility that the data obtained did not cover average conditions. The data of the Division of Hydrography, U. S. G. S., of course, gives us something more ideal upon which to base our estimates, as a rule extending over a longer period of time, are more accurate, and available when wanted. The question arises, how long a period of time should we be satisfied with in this kind of work? When will additional hydrographic data add little or nothing to the results? The writer ventures to limit this to thirty years. The Hydrographic Survey Department should receive hearty support from the Territory for many years to come, so as to obtain valuable data for these islands.

On the other hand, the *demand* for water is fairly well known in a general way, considering the present methods of irrigation. Of course, if it were possible for the cane to withstand periodic shortages in the gravity supply by supplementing this supply with pump water, there would be a greater demand for the flood water.

Capacity of the Ditch

The capacity of a ditch depends upon the cross-section and grade, and the degree of roughness of the wetted perimeter. An excessive grade will produce too great a velocity in the water, which will erode the sides and bottom of the ditch. Of course, a masonry-lined ditch will withstand higher velocities than an unlined ditch. The maximum velocity for unlined ditches should be about three feet per second, preferably not greater than two feet. Of course, this again depends upon

the nature of the material through which the ditch is excavated. Masonry-lined ditches withstand velocities of from six to ten feet per second, provided the water carries no grit. It is important that the water in masonry-lined ditches be comparatively free from grit. There are instances on East Maui where grit-laden water running at a velocity of about four or five feet a second eroded the floor of the ditch about one inch in eight years' time. Taking this into consideration, it will be seen that comparatively larger investment is warranted in preventing sand and gravel from entering masonry-lined ditches. In the most recent ditch construction on East Maui, provision has been made to strain the water as it is taken from the stream, so as to remove rock and large gravel. The finer material is being taken out by passing the water through a settling basin. It is reasonable to believe that it is this fine material which erodes the masonry-linings, because the coarser material is not carried along by the ditch flow. It is merely deposited in the ditch near the intake, and causes considerable trouble and expense in having it removed. The stream gravel and sand have to be reckoned with, especially in the case of masonry-lined ditches. The grade of the better East Maui ditches is a slope of about one foot a thousand, which produces for the usual ditch cross-sections a maximum velocity of three feet per second in unlined ditches and six feet per second in lined ditches. Where a ditch derives its water from several streams which it crosses, the problem presents itself of increasing the capacity of the ditch as additional streams are taken in. This complicates the hydrography of the problem oftentimes, because these streams may not all rise and fall at the same time. They may be out of synchronism. A study of their flows over several years' time will furnish data for solving this problem, so that good average conditions can be obtained.

Unit Construction

Since sugar cane irrigation is continuous throughout the year, there is demand that the supply ditches be continuous in their operation. This makes it very difficult to make repairs. Why not follow the scheme used in making machinery layouts, viz.: construct the ditch system in units? In other words, build two smaller parallel ditches instead of one large one. In times of small flow merely use one of these two ditches, thus making it possible to have the other shut down for repairs if need be. There is a possible additional argument in favor of the double unit ditch system. One of these ditches could be completely lined so as to be fairly water-tight, and be used for carrying the dry and normal weather flow; whereas the other ditch could be unlined and used to carry flood flows. Temporarily the unlined ditch could carry the normal or dry weather flow, should the lined ditch require repairing. Both of these ditches should deliver water at an elevation that would cover the fields which either are to irrigate. On East Maui, in a general way, each plantation has an upper and lower level supply ditch. This, however, does not fulfill the function of the double unit system outlined above, because the low-level ditch in each case does not deliver water to the plantation so that it can be distributed by gravity to the upper fields.

It is desirable to arrange ditches with overflows at points at which the waste water will do no damage, and yet at sufficiently close intervals to prevent the ditch from overtopping its banks during flood conditions. Overflows call for a "free board" on the ditch. The amount of desirable free board depends upon the length of the waste ways or overflows. Long overflows will discharge a given quantity of water for a much shallower depth on the crest than a short overflow. It is this depth of water on the crest that decides the amount of free board necessary in the ditch. Short, infrequent overflows call for greater free board. It becomes a problem in which the cost of additional overflow capacity is balanced against the decreased cost resulting from constructing the ditch less deep. Free board from three to six inches is not uncommon.

Protecting Ditch Banks

There is another method of protecting the ditch banks from being overtopped in times of flood water, which has been tried to a limited extent on East Maui, viz.: the use of automatic intake gates. These are actuated by floats which close the gate when the main aqueduct is full, or partially close the gate so as to prevent the bank of the main aqueduct from being overtopped. Of course, this same operation can be approximated by hand-operated gates. In the hand operation, if the ditch tender is too conservative, he will keep the intake gates too closely set and run the danger of the water not being taken in when there is room in the main aqueduct for it. On the other hand, if the ditchman has not set his gate sufficiently close, unexpected showers may cause more water to be introduced into the main aqueduct than it will carry, and thus cause an overtopping of ditch banks. This is undesirable because there is a danger of the bank being washed out and the ditch breaking, or even if this does not happen the water wasted may damage property below the main aqueduct by flowing where it is not intended it should. Automatic intake gates have additional value, possibly their greatest value, in preventing much grit from entering the main ditch by automatically closing at times of flood waters, which are usually heavily laden with sand and gravel. These gates, although automatic in operation, require considerable maintenance attention to keep them in running order, and the question arises whether this additional maintenance cost is justified.

Ditch Lining

Ditch lining is an important phase of ditch construction. In this connection, the important thing to decide is: "Will the saving of water warrant the cost of lining the ditch?" Of course this depends upon the amount of seepage and leakage that is prevented by the lining. In planning a new ditch, the seepage and leakage losses cannot be foretold nearly as accurately as they can be measured in existing ditches. The losses which will exist in the proposed ditch can only be estimated by assuming that they will equal those in an existing ditch through similar material. It appears to be good business before deciding upon lining a ditch to determine by measurement, the amount of seepage and leakage losses,

in the existing ditch, the lining of which is under consideration, or those in a ditch similar to the proposed ditch, as the case may be, and make an estimate of whether the cost of lining the ditch will be repaid by the water saved. In carrying on these water measurements, it would be well to divide the ditch up into sections and determine the seepage and leakage losses in each section, thereby locating the portions of the ditch leaking most. It may thus be found that it will only pay to line certain portions, the most leaky ones first. Other conditions being equal, the discharge end should be begun first. This is based on the theory that the water becomes more valuable as it is conveyed along the ditch and nears its destination. This is particularly true of ditches that take in their supply from the various streams crossed. At flood times the last stream or the last few streams crossed may have sufficient flow to fill the ditch. Under these conditions, lining in the lower section would be working 100 per cent of the time, whereas the lining of the main aqueduct in the section in which the first stream is taken in, is only in useful operation a portion of the time.

Although the principal function of ditch lining is to prevent seepage and leakage losses, it does decrease the operation and maintenance of the ditch, in many cases by preventing vegetation from growing on the banks of the ditch, which would otherwise call for labor to clear it away. It also prevents erosion of the banks and gives greater carrying capacity for a given cross-section and grade of ditch.

Types of Ditches

Various types of lining have been employed: cut stone set in mortar, plaster lining placed by hand or by cement gun, pre-cast concrete slabs, concrete lining cast in place either by the use or non-use of forms. Other types of lining have been tried, only to a very limited extent, such as asphalt and crude oil. In former years, when labor was cheap and there were few roads through the rough country traversed by the ditch, cut stone lining was employed to a great extent. There is always a probability that this type of lining will not prevent as much of the seepage and leakage as other forms of lining. In other words, the lining itself may be leaky, depending upon the care with which it has been placed. It has this advantage: cut stone will resist wear of grit-laden water quite successfully, and this type, well backed with concrete, is therefore being employed where excess velocities are to be combated, such as in ditches having excessive grades. Cut stone lining in out-of-way places obviates the necessity of transportation of a great deal of the material that concrete lining would call for, and therefore fills a want in such places.

Pre-Cast Ditches

The use of pre-cast concrete lining is justified in places where it is not feasible to close down the ditch for a long enough period of time to give concrete cast in place sufficient time to harden. Pre-cast concrete requires less form work than concrete cast in place behind forms, but has this objection: At least this is the experience of the Wailuku Sugar Company, which carried on this

method of lining quite extensively six years ago. There is a far greater tendency for the ground water to get behind the pre-cast concrete, and should the ditch lower suddenly, it would force the lining away from the bank. This is probably due to voids behind the lining. To overcome the tendency of the wall lining to tip into the ditch, the Wailuku Sugar Company has put in pre-cast concrete struts across the ditch at intervals, thus holding the two walls apart and preventing them from moving inward. Unlike pre-cast concrete lining, concrete lining cast in place shows very little tendency to fail, because of water pressure behind the concrete at times of low water in the ditch. Other things being equal, pre-cast concrete lining costs more than concrete cast in place, due to the additional cos of placing the slabs of concrete after they have hardened.

Plaster Ditches

From 1912 to 1917, a large percentage of the ditch lining on Maui was done by the plaster method. Plaster was supposedly about three-fourths inch thick, placed either by hand or by cement guns, embedded in which was a poultry wire mesh, acting as a reinforcement. It is almost impossible to tell today whether a given portion of this plaster lining was done by hand or by the cement gun process. In either case, it has been more or less of a failure. This kind of lining on the floors of tunnels and open ditches has almost entirely disappeared. Initial failure of a floor thus lined may be due to the fact that it has not withstood walking on it. After cracking, the water gets under the edge, and a high velocity will cause the floor lining to roll up in a manner similar to a roll of carpet, and be carried down the ditch. The sides withstood the test of time somewhat better but in many cases large portions of the lining on the sides have disappeared. It would appear that a sudden decrease in the depth of water in the ditch will, in many cases, leave water behind the plaster lining, which will force the lining off the side of the ditch. (Possibly this same action caused the first breaks in the floor lining.) Of course, after the floor has gone there is little chance of getting unbalanced hydrostatic pressure behind the wall lining. This accounts for much of the wall being intact, but doing little useful work.

There is a probability that plaster lining would have proven more satisfactory if more care had been exercised in doing the work, but the cost would have been greatly increased. One of the difficulties encountered in plaster lining is to get the plaster of uniform thickness. If the sides of the ditch are not perfectly planed, there is always the possibility of having the plaster thick in one place and very thin in another. In fact, it is almost impossible for the plasterer himself to tell how thick he is getting the plaster, because, after the surface is covered there is no feasible way of telling how thick the plaster is.

The method used in lining the Gage Canal of Southern California, a number of years ago, might have been successfully employed, viz.: by bringing the ditch sides to a practically plain surface, and then using guides to assure uniform thickness of plaster. Of course, the extremely thin places in our lining fail first. There is another reason why ours have not been as successful as the Gage Canal. In Southern California they have seasonal irrigation. Before starting up irriga-

tion for the season, the lining of the ditch is gone over from end to end, and put in good repair, whereas with us, this is practically impossible because the ditches cannot be shut down for a sufficient length of time to carry on this kind of work. The claim that the cement gun places the mortar immediately after the water is introduced, and that it is not disturbed after it commences to set, and thereby produces a stronger plaster than that placed by hand, is not always true in practice. The man operating the cement gun does not always build up the portion of the lining to the desired thickness, before passing on to a new place. In other words, he may go back over work that has been placed several minutes previous to build up the plaster to the desired thickness, and in so doing disturb the initial set of the underlying portion. One of the principal costs of plaster and concrete lining is that of cement. Usually there is as much cement in plaster an inch thick as in concrete three inches thick.

Concrete Ditches

Concrete ditch lining which has not been subjected to high velocities of grit-laden water and the aggregates of which are hard, sharp material, has stood the test of time. Coral sand as an aggregate does not give a surface that resists wear as well as hard, sharp, crushed rock sand, neither does it produce a strong concrete. Its comparatively low cost in many localities, however, justifies its use if the lining is not to be subjected to excessive wear. Pump water and gravity water which have been standing in reservoirs will not contain grit in such quantities as to erode masonry-lining having coral sand as an aggregate, providing the velocities are moderate.

The cross-section of a ditch is determined by the conditions which have to be met in each case. If the aqueduct is tunnel, the walls are nearly vertical; if, open ditch on a steep side hill of hard material, the walls are only slightly sloped; if open ditch across comparatively flat country, the walls are usually given considerable slope. In casting concrete lining on nearly vertical walls, forms are used, usually on the water side only, backfilling where excessive excavation (as in hard material which blasts out unevenly) would otherwise give too thick a lining. It is well to make this backfilling of clean hard rock, if available at moderate cost, so that the concrete will bond with it, thus making it possible to reduce the thickness of concrete and still have a masonry wall of normal thickness. Where conditions are such that it is feasible to give the sides of the ditch considerable slope, a thinner lining can be used than would otherwise resist a possible hydrostatic pressure produced by water which might collect behind the lining, followed by a sudden drop in the ditch flow. Since the floor has to withstand the greatest wear, by material being rolled along it, logically, it should be made thicker and of better material than the sides. In addition to this precaution, it is well in some cases to give the floor the form of an inverted arch so that any rolling and sliding grit is distributed more evenly over its surface. If the floors are flat, there is a tendency for the wear to be concentrated along the angle between the wall and floor.

There are several advantages in casting concrete lining in place without the use of forms. This can always be done on the floor and on sides of sufficient slope, say a minimum of 1 to 1. Not only is there a saving, due to the non-use of forms, but a great advantage in being able to apply the plaster finish to the concrete before it has begun to set, and thereby insure a bond between the two. When the plaster finish coat is applied to the concrete after it has set, which is necessary if forms are used, there is much more of a possibility of not having a perfect bond. There is a tendency for plaster finish exposed to the sun to spall off in patches, not necessarily the first few years, possibly after it is several years old. This is probably due to unequal expansion and contraction of the plaster and concrete, resulting from variations in temperature. This tendency is aggravated if the mortar composing the plaster is richer in cement than the mortar-aggregate of the concrete. Of course, floors can and should have the finishing coat applied immediately after casting the concrete, and special care should be taken in finishing with a thick coat fairly rich with cement, so as to withstand the excessive wear to which they will be subjected. A rich plaster coat on the floor, if applied before the concrete is set and well worked in, will not spall off, especially if at all times protected from changes in temperature by continuous flow of water in the ditch.

Expansion Joints

Joints to take up expansion and contraction, due to changes in temperature, are advisable to open ditch lining under most Hawaiian conditions. Otherwise unsightly cracks will appear at various intervals. In localities and under conditions where there is only a very slight change in temperature the year round, this is not true. For example, non-reinforced concrete tunnel lining, in the Hawaiian climate, will not crack, even if no expansion joints are provided. Non-reinforced concrete lining in open ditches under ordinary conditions in Hawaii will not crack if expansion joints are located at about fifteen-foot intervals. These may be some kind of slip joints to prevent leakage through them, or they may be a plain construction joint having strips of roofing paper separating the two adjacent blocks of concrete lining. If placed at the suggested intervals, these plain joints will open so slightly, due to contraction, that the leakage through them is only slight. On the other hand, expansion joints placed some distance apart, such as at either end of a reinforced concrete flume of one hundred feet or more in length, will require some specially designed slip joint or flexible diaphragm joint to prevent leakage, due to the excessive opening of the joint when the temperature of the concrete is lowered slightly.

The exposed surface of the concrete lining may be left without any finishing plaster coat. However, it is usually advisable to use some kind of a finish. Unless there has been an excessive quantity of mortar aggregate used in the concrete, there will probably be considerable seepage through unfinished concrete. The strength of concrete is directly dependable upon the strength of the mortar aggregate. To get a strong, dense concrete requires excessive mortar rich in cement. A less dense concrete, but just as strong, can be made with a less quan-

tity of this mortar aggregate with a resulting saving in cement, and cement is the costly item in concrete work. An economical way to get the desired result in ditch lining, is to make a strong, less dense concrete and finish it with a more impervious plaster coat. This will work out satisfactorily in case the plaster coat is applied on the fresh concrete and a perfect bond is thus obtained. Of course, this procedure necessarily presupposes that the concrete is cast without forms.

Grout-Painting

Grout-Painting is another method used in finishing the exposed surface of concrete lining. It consists of applying a cement grout with a paint (or white-wash) brush to the surface of the hardened concrete, which has been cast behind forms, and from which the forms have been removed. This grout may be a wet mixture of cement and sand or merely cement alone. Very seldom will this grout stay on the concrete any great period of time, probably due to a lack of a bond between the two. On the other hand, there is a possibility that the surface pores of the concrete are filled with grout which continues to play an important part in making the concrete impervious. The efficiency of grout-painting is doubtful because it does not produce the hard wearing surface that is obtained by using a plaster finish.

Cement mortar plaster used with or without a concrete backing for ditch lining may have its surface finished in two ways: (1) a "glazed" smooth surface, produced by the use of a steel trowel; (2) a sand finish, produced either by the use of a wooden trowel or by brushing the surface before it is set with a whitewash brush. A "glazed" surface exposed to the sun will tend to become checked with a great number of surface cracks; whereas, under similar conditions, a sand finish does not have this tendency. Probably the sand finish produces sufficient shade and shadow effect to prevent the surface from becoming as highly heated as the "glazed" surface. Accordingly, it is well to give a sand finish to an open ditch lining, and a steel trowel finish to a tunnel lining. The smooth finish produces a slightly greater carrying capacity for a given cross-section than the sand finish.

Of the various ditch linings, considered above, the most satisfactory from cost, maintenance and utilization point of view, is the non-reinforced concrete, cast without forms and finished before it begins to set with a cement mortar. Of course, this method can only be used where it is feasible to give the ditch banks slopes of one to one or flatter. When a power-driven concrete mixer is used, when material is delivered to it in cars, and when the entire equipment so moves along, as the lining advances, that the fresh concrete is discharged from the mixer near enough at hand to obviate the use of wheelbarrows or carts, the labor required to place a 3- or 4-inch lining varies from 100 to 140 square feet per man a day.

After all the foregoing statements concerning ditches and ditch lining, it must be admitted that each project or portion of a project is a problem in itself, and no hard and fast rule can be laid down as to location, size, grade and kind of lining to use.

Genetics and Its Relation to Cane Production*

By F. G. Krauss
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A questionnaire was sent to twenty-five representative members of the Association of Hawaiian Sugar Technologists, to which sixteen replies were received. The following are the names of those who contributed information. After each name appears an index number. These numbers are used throughout the text in place of the names, for the sake of brevity: A. D. Shamel (1), L. D. Larsen (2), Y. Kutsunai (3), Frank W. Broadbent (4), W. W. G. Moir (5), H. P. Agee (6), W. P. Alexander (7), Wm. Wolters (8), C. E. S. Burns (9), J. N. P. Webster (10), Douglas Cooke (11), John C. Thompson (12), J. S. B. Pratt, Jr. (13), John H. Midkiff (14), and C. F. Poole (15). The questions and their answers follow:

QUESTION I. (a) What are the most important problems in your sugar cane improvement through breeding? Please enumerate.

ANSWERS: To determine the heritability of characters and of variations of the various varieties of cane (3).

To combine the most desirable characters of various existing canes in new sorts. Characters sought are, *adaptability, heavy cane yields, good quality ratio,* and *high degree of resistance* to disease (mosaic and eye spot (4)) and injury (3). Desirability of having a good substitute cane on hand (4).

The problem is to secure an understudy to H 109 which will have equal cane tonnage, but which will also be immune to the eye spot leaf disease and *be a better, early* ripening cane (7).

To produce a high yielder, . . . a good ratooner, as we ratoon a great deal, ... a cane which is disease resistant . . . a cane which can substitute any one of our standard varieties such as H 109, or D 1135, in localities where they do the best (8).

To develop a cane equal to or better than H 109, but with a quality ratio like that of Lahaina, to create better uniformity in the stand and stalks of present standard varieties (10).

The ultimate object of all cane breeding is to find varieties which under certain conditions of environment will produce sugar with greater profit than the so-called standard varieties hitherto grown. This result is obtained by either increasing production per acre, or with hardier canes, producing sugar at less cost per unit, . . . (conditions of environment enumerated in detail). . . . Whether a seedling will produce sugar with greater profit than the former standard variety is determined by its degree of adaptability to any given set of conditions. A single change in these conditions may necessitate a different variety of cane (4). . . . Determining the variety most suited to any given environment (11).

To secure pure line strains of the variety in question through progeny tests. To secure superior types from these pure line strains, after a series of progeny tests extending over several plant crops and ratoons. To secure possible mutations superior to the general run of the progeny under observation and to eliminate undesirable mutants. To secure larger yields through type selection rather than by a cumulative plus variant selection. To secure strains that will be resistant to Pahala blight and other local diseases (12).

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

Our biggest problem at Waialua is to find some cane that will give us the same yield that we get from H 109 and which is also resistant to eye spot. It is our belief that we are more likely to find this cane among some of our new seedlings, rather than by selection within H 109 (14).

At Waialua we are severely hit by eye spot disease and we believe it is only a question of time when we shall have to find some new variety to replace H 109. That is the end we are working towards (14).

QUESTION I. (b): If you are practicing vegetative, selective breeding (bud selection), what plant characters are involved in your selections? Please enumerate each character considered and state the extent to which these characters are correlated.

ANSWERS: Selection is based on cane yield and the quality ratio. These two characters seem in general to be correlated. In case the cane is not weighed, the volume of the cane is judged. The weight and the volume are very closely correlated (3). Freedom from disease and weight of cane in pounds per foot of row (4).

Type of tillering (stooling). Earliness of tillering. No definite correlation data have been secured but good indications of correlation have been observed (5).

To date plant characters, **per se** (by themselves) have not been involved. Weight of cane per acre has been the basis upon which progenies have been selected. We are working with mutations showing different physiological characteristics, but are not able to report any definite correlations (7).

We first select outstanding stools having eight or more stalks each of uniform size. Greatest yield of sugar per acre over a period of years is what we are after. We want a cane that stools out early in order to close in quickly and yet carries through to harvest without going back (9).

So far no other character has been found that can be correlated with sugar content except possibly vigor of growth (11).

Plant characters noted in selections. Type of stool which classifies the stools as erect or upright, semi-erect, and recumbent and intermediate grades between the extremes. Shape of stool in which stools are classified as standard, fan, and birdnest types, the standard types of stool being most desirable and found to a large extent erect and upright. The recumbent type is associated more with the birdnest type of stool. Manner of stooling which includes the manner in which the sticks originate from the seed piece or appear above the ground, the compact mass of stalks originating from a single eye being more desirable. Uniformity of stalks is also considered in the first selection of stools (12).

We expect to do more or less bud selection work in the near future. We will then stress eye spot resistance correlated with satisfactory sugar yield.

QUESTION I. (c): Has your selective breeding, either in bud selection or among your hybrid seedlings, as well as mutations, in either or both materials, progressed far enough to establish definitely improved lines in the qualities sought after, and to what extent?

ANSWERS: 'It is probable that the sugar cane varieties of the future will be those which will be hybrids between hardy types or species of cane and the group or species which includes most of our standard canes of today; or, better still, progeny of these hybrids in which the hardy species or type has been diluted until we have quarter-breeds, eighth-breeds and possibly sixteenth-bred canes.'

In this class of work we have been severely handicapped through lack of the best breeding material and we will remain under this handicap until we successfully establish in Hawaii the Kassoer variety (and other canes of its type) which gives such promise in this work.

The earliest work in producing hybrid canes that we know of is that of Kobus in Java dating from 1897, or thereabouts, when he crossed the standard canes of Java with Chunnee, a North Indian variety, for the purpose of obtaining relief from sereh. Some of the P. O. J. canes, such as 36 and 213, which are making such a record for themselves, are the

result of this early work of Kobus. Later, Kassoer was used in Java as a breeding cane, Kassoer being a wild hybrid between *Saccharum spontaneum* and *Saccharum officinarum.*

From a breeding standpoint Kassoer offers more interest today than any other hardy cane variety. In the absence of this cane we have struggled during the last few years using our so-called Uba (which is not the Uba of Natal but probably Zwinga or some other inferior type) and our efforts have had some success. From comparatively few hybrids we have some commercial possibilities. If we could have had thousands of hybrid canes to select from instead of a few hundred or so our chances would, of course, have been better, and it is the readiness with which Kassoer lends itself to breeding work, as compared with Uba, that is one of its attractive features. From crossing and recrossing Kassoer in Java they now have some vigorous large stick canes which are attracting attention on account of their hardiness and drought resistance. Among them are P. O. J. 2714 and 2725, twin canes from the same arrow, selected from 25,000 seedlings, and possessing the following interesting pedigree:

1. GLAGAH ($\frac{1}{8}$) (*S. spontaneum*) 2. BLACK CHERIBON ($\frac{1}{8}$) (Louisiana Purple)	Kassoer ($\frac{1}{4}$)	P. O. J. 2364 ($\frac{1}{2}$)	P. O. J. 2714 and P. O. J. 2725
3. BLACK BANDJERMASIN ($\frac{1}{8}$) (Black Cheribon or Louisiana Purple) 4. LOUZIER ($\frac{1}{8}$)	P. O. J. 100 ($\frac{1}{4}$)		
5. BANDJERMASIN ($\frac{1}{4}$) (Striped Preanger or Louisiana Striped) 6. FIJI ($\frac{1}{4}$)		E. K. 28 ($\frac{1}{2}$)	(Selected from 25,000 seedlings in 1917)

We trust that in a few years we will be able to show Hawaiian grown canes with equally interesting pedigrees, for we expect to combine the splendid characters of such canes as Yellow Caledonia, Badila, H 109 and D 1135 with the hardiness and disease resistance of such canes as Uba and Kassoer. This is the objective in our cane breeding work which interests me the most. We are working for commercial canes of high weed-suppressing ability, strong ratooning power,—those which will make the most efficient use of the essential factors of sugar production which we have heretofore enumerated: Man-days of labor, Acre-inches of water, Acres of land, and Acre-months of growing time. This involves, as a matter of course, disease resistance or immunity (6).

Some of the hybrids have established improved lines to the extent that they are replacing the older varieties (3).

No (4).

It has puzzled me that in spite of the thousands of seedling canes that have been raised since H 109 was "discovered" we have apparently made little or no progress in the isolation of a cane that would be as superior to H 109 in any quality as H 109 was superior to Lahaina in a lot of qualities. Since H 109 came to light it would seem that practically all island efforts in cane breeding were based on the idea of propagating large numbers of seedlings with the hope that we might have the "luck" to again obtain a superior one. (Our technique has been boiled down to a fine point, thereby proving some progress, but a principle or rule of actions for making crosses based on proven genetical procedure is lacking.) (4a.)

In *seedling* work, several promising canes have been secured that are equally as good as our standard varieties under certain conditions. In *bud selection* work, no conclusive data have

been secured, but improvement in planting material has been noticed as a result of this project (5).*

We think we have several canes that at least equal H 109 (9).

It is hoped that with the bringing in of the Java seedlings further progress will be made along the lines of disease resistant cane.

Several hybrid seedlings have been grown at the Station which show decided improvement over former standard varieties. H 109 is now planted in place of Lahaina on the lowlands, and several Tip and Uba seedlings have been developed that may take the place of D 1135 and Tip canes on the upper fields. H 109 itself will probably very soon be replaced by its own offspring or those of Lahaina.

With bud selection improved lines have not yet been definitely established (11).

Results from selective breeding. Selective breeding, either in bud selections or among our hybrid selections as well as mutations, has not progressed far enough to establish definitely improved lines in quantities sought after. Bud selection requires more attention than can usually be given to that phase of the cane industry, so much depending on the proper examination of the progenies when a year old (12).

We have found one or two seedlings that seem to give fair returns and at the same time to be quite resistant to eye spot (14).

. . . We have just finished five years of study of this problem in sugar cane. I feel very sure that notwithstanding many disappointments in the pedigree selection progeny tests as much progress has been made in sugar cane bud selection work as was made during the same length of time in our citrus work. I believe that with five more years of concentrated and intensive effort the pedigree sugar cane work can be brought to the same stage of commercial value and utilization as has been the case in the citrus during the first ten years of our work (1).

QUESTION I. (d): 1. What are the most outstanding mutations (sports) that have thus far been discovered? 2. Do the newer seedlings or old established varieties show the greater tendency to mutate in vegetatively propagated material? 3. Are mutations most likely to occur in the plant crop or any succeeding ratoon crop? 4. Are more mutations found in favorable conditions than in unfavorable conditions? 5. Do different cultural conditions appear to exert influence upon mutation ability? 6. In what quantitative, visible characters does the plant most frequently mutate, and to what extent, if any, do these characters correlate with higher total sugar yields, either qualitatively or quantitatively?

ANSWERS: (d). 1. Rose Bamboo, Yellow Tip, Striped H 109, Striped Yellow Caledonias, Striped D 1135, White D 1135 (3).

A few color mutations (4).

We cannot at this time designate any sports as outstanding, since they are now only in the first planting and only a few months old (7).

We have found several cases of Striped D 1135 in ratoon cane. So far we have not noticed any in the plant cane. This may simply be a case of missing such a mutation or sport in the plant (cane).

No outstanding mutations have so far been discovered (9).

No outstanding mutations have been found, all mutations found this year being now planted out with the parent varieties of the mutations. Several mutations have been found this year with the Manoa Tip seedlings and 8900 series as well as the 1923 Oahu propagated seedlings. Newer seedlings show the greater tendency to mutate in vegetatively propagated material than old established varieties. Mutations occur quite frequently in plant cane, but whether they occur more frequently in later succeeding ratoons has not been noted here. As far as I have noticed, adverse growing conditions exert a greater influence upon mutability. Has not been noted (12).

* Alexander, of Ewa, makes practically the same remarks.

The newer seedlings seem to show greater tendency to mutate. We have found more mutations in the ratoon crops, but this may be simply because we have not observed them closely enough. We have not found that cultural conditions make canes more or less mutable (14).

(d). 2. Do not know. More mutants were found in H 109 than in Yellow Caledonia, but this difference may be due to the relatively larger amount of labor spent in looking for mutants in H 109 (3).

I believe that the newer seedlings show a greater tendency (to mutate) (4).

Not enough work done to say definitely yet. . . . (5).

We have obtained sports only from H 109 (7).

(d). 3. Do not know, but plant crop is preferred in selection work (3).

No data (4).

Mutations may appear just as readily in plant or ratoons (5).

We have obtained about 75 per cent more mutations from plant fields. This indicates perhaps that plant crops show a greater number of mutations than succeeding ratoons, but beyond this we cannot say, not having made a study of this point (7).

(d). 4. Do not know (3).

No data (4).

Environmental factors have greater influence than anything else (5).

No data (7).

With D 1135 it has been noticed that this cane is very apt to mutate where conditions are severe, as when growing on palis, or where water is a limiting factor (10).

(d). 5. Do not know (3).

(d). 6. Do not know of ever seeing a quantitative mutation, though such appears to be the object of selection. On the other hand, I have seen qualitative effects such as color mutations (4).

The only visible characters that are known to be definitely mutable are color and markings of stalks; type, color and shape of leafy top; and size of stalks and stool in relation to general stature. Yet these characters are correlated, some qualitatively and some quantitatively with sugar yields. For example: Caledonia Ribbon, a color mutation of Yellow Caledonia, has always had a somewhat better quality ratio than Yellow Caledonia, but in tonnage of cane it is slightly lower. Red Tip, the solid, red-colored stalk-sport of Striped Tip, has always been known to be very inferior in tonnage of cane. Yellow Tip, the solid, yellow colored stalk sport of Striped Tip, may be readily distinguished in type of growth and leafy top characteristics and in many localities is found superior to Striped Tip in yield. Black Tanna, the purple mutation of Big Ribbon, is lower in yield than Big Ribbon and is not suited to as varied conditions as is Yellow Caledonia, the yellow mutation. White D 1135, a yellow mutation of Striped D 1135, is poor in yield. Hairy Yellow Caledonia is a very inferior cane as compared to Yellow Caledonia (5).

"(7)" mentions several of the above observations.

Our mutations have not been under observation for a sufficient period of time to attempt to correlate mutation characteristics with sugar yields (7).

The visible characters in D 1135 when mutation takes place, consist of a narrow stripe, either dark purple or green, the former being more easily found. . . . Such conditions are inferior as to size of stalk and growth in some cases (10).

QUESTION I. (e). 1. How are your progeny tests conducted, and how do you control the environmental influences under which these cultures are grown? 2. Do you feel that your bud selection work has resulted in the establishment of definitely improved strains or varieties or that you are making satisfactory progress towards your goal? 3. What appear to be the greatest difficulties of the work in hand? 4. Can you suggest any improvement over our present methods?

ANSWER: (e). 1. Progenies are given ample room to develop so that their relative (inherent) capacities only become the limiting factor (3).

Progeny tests are conducted on a field scale where the environmental influence is under no more control than in the usual plantation cane field (4).

Progeny tests are conducted under as near average plantation conditions as possible. They should *not* be given the very best treatment. If possible they should be given treatment below average and allowed to ratoon before selection. All work (selection?) should be done in material that has been allowed to reach maturity—that is, two years of age (5).

The progenies are planted for comparison . . . adjacent to plots of ordinary plantation (H 109) cane. (It is very important that the seed for these checks be obtained from cane of the same age and environment as the progeny material.) Fertilizers and irrigation are applied as uniformly as possible to progeny and control plots. Even so, variation in stand and soil difference are very great and tend to overshadow what may be hereditary influences (7).

Our progenies are all planted with checks of H 109 for comparisons (9).

We avoid, if possible, varying environmental influences. The plot chosen for progeny work must be practically level and the soil as uniform as possible. Only such seed is planted as will give even germination, since a good stand is an essential. Uniformity of germination is further controlled by planting in boxes and setting out uniform plants.

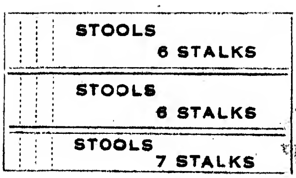
An attempt has been made to avoid unevenness of light, aeration, and water by placing the plants in rows five feet apart from center to center. The amount of water given is under careful control. Likewise fertilizer. Border rows are not included in harvest data (11).

Progeny Test Areas

The usual practice has been to select stools in a field and plant the seed pieces of each stool or progeny separately, spacing the seed from 6 to 12 inches apart. The cane from which the seed or stools were selected was generally one year old or thereabout. However, a change has been made in this year's selection. In selecting for progeny planting from the plantation fields, it was thought advisable this year to select stools and seed from the best fields and from cane which was being harvested. The idea was advanced that only when a field is being harvested, is one able to judge the kind of cane correctly. This method eliminates the usual stripping which is necessary when the selection of stools is done in year-old cane. However, the general study of the stools and judging the stools selected according to their superiority over the surrounding stools which is possible with young cane where the outstanding stools are marked and cut for progeny planting, are wholly impossible with selection in two-year old cane. The method employed this year will probably bring far better results as a whole, although progenies will be compared on a smaller scale, single stools representing progenies where formerly each progeny occupied a certain area or a part of a row.

Where possible, the best stools have been selected, but due to the great difficulty experienced especially with cane fallen down and covered with trash it has been impossible to select the best stools in comparison with the surrounding stools. However, a certain standard and type of stool was first adopted for the field, this being the result of careful examination of stools in the burnt area being harvested. After satisfying oneself with the best type of stool in the field, as many stools coming within range of the selectionist's vision and examination were selected and planted out.

When planted out, all stools having the same number of stalks were planted to the same area. For example, all of the stools with six stalks each were first separated and planted one stool to a line of a certain length, depending much on how great a spacing was allowed between seed pieces. The whole width of the plot was planted to stools with six stalks to the stool, when a path of three to five feet was marked down along the back line of the first section as outlined in the diagram. Another section of lines of the same length was then planted, to stools of six stalks each. The length of the lines was increased whenever stools of more stalks were planted.



This method of planting progenies not only facilitates the harvesting of progenies but also eliminates the more complex method of staking out progenies and the heavy expense of stakes. By this method only a few good stakes are required, where hundreds were formerly required, back line stakes of old boards being used in the paths between sections.

Besides selecting stools in the harvesting field, effort was made to select the best seed possible for progeny planting. By the best seed is meant seed from what may be termed good, large, uniform sticks above the average. This enabled the selectionist to cover a large area and to get the best sticks in the area examined. Although this method does not enable one to get a progeny growing on a large scale during the first year, it should give the selectionist the best result. The best seed is planted and spaced such that each progeny will be distinctly separated. A greater number of progenies, which represent only the best sticks in the good stools, is the result of such a selection. Such a selection eliminates all the work of harvesting a whole progeny by stools and of calculating the necessary data and the final selection of the best stool in the progeny for further tests, discarding the other stools of the same progeny.

This method makes it necessary to select for further planting after a year's growth, for a careful examination must be made of each individual stool or progeny.

With regard to harvesting progenies this year in two-year old cane, the following method has been employed. Due to the tangled mass of cane, it is wholly impossible to weigh by individual stools, since such a process would incur a heavy expense unless burnt, during which conflagration the stakes would probably be charred. The cane is cut by progenies in the usual way, scaled and computations made for tonnage per acre and the weight per stick whenever possible to count the stalks. The usual method of selecting the stools above the average for the day or over a certain uniform area has been substituted such that another higher average is taken of all of the progenies above the general average of the area or day, and all stools ranking above this higher average are selected for progeny planting. This method raises the average of the field and allows only the best of the progenies to be harvested.

This method is being used in harvesting both plant and ratoons, the ratoons being harvested and planted to check up on the plant cane results.

(e). 2. I believe that our bud selection has resulted in the establishment of improved strains, although we are making only slow progress towards our goal (12).

The data on bud selection are conflicting, and need more time to decide this point (3).

Have no evidence as yet to prove the establishment of a definitely improved strain of cane as the result of bud selection work (4).

Yes, making satisfactory progress, as fast as can be expected (5).

We hope that we are making progress, but often it appears as if we were still far from our goal. Quick results cannot be expected (7).

So far we have not established any definitely improved strains or varieties. We have over fifty progenies extended into areas of sufficient size to give us some very interesting data after they are harvested this year (9).

We cannot say that bud selection has resulted in definitely improved strains because there is still a good deal of variation within progenies. However, the results obtained from some progenies are along the right lines and it is only a matter of time when we will know more about them. Spreading the better progenies out to large areas where environment plays a lesser role and being able to get actual harvesting results is very important (10).

Too soon to state definitely that bud selection has resulted in the establishment of improved strains. One of our Yellow Caledonia progenies seems to have made a very good record, but it needs further test. It was six or seven years after its creation before the superiority of H 109 was proven with any degree of certainty. Perhaps the reason people are too quickly becoming discouraged with bud selection is that they were too optimistic at the beginning (11).

(e). 3. The difficulty of detecting the invisible characters and the masking influence of the environment (3).

A plan of proved merit suitable for use under plantation conditions (4).

The greatest difficulty of the work is the elimination of progenies to a point where proper experimental plantings with checks may be made and not take up too large an area (5).

. . . To be able to isolate (locate) the mutations. (b) To eliminate conflicting environmental influences in tests, so that the inherent qualities can be measured. (c) To prove that the strain is permanent and not instable (7). (Part of this (7) statement was not very clear and interpretation is given, K.)

(1) Inability to recognize mutations other than those of color.

(2) Practically impossible to absolutely control environments.

Our present method of planting the cane in holes spaced five feet apart is our latest attempt at controlling environment.

(e) 4. Detailed genetical study of the cane plant with the view of establishing visible indices correlated with invisible characters may help (3).

If present methods need improvement they probably need a more scientific and accurate control of the details (environment, etc.), all of which, I believe, will take the work away from rather than towards plantation conditions. It appears to me a job requiring special attention (4).

The first recommendation I would make is to study more closely the ratoons of progeny plantings. A second is to work with fewer progenies. A third is to allow all material to go through to maturity before securing yield figures, and the fourth, to study the cane plants in progenies a great deal closer to identify characteristics of structure and habit that are usually associated with different types (5).

Our selections must be based upon some characteristic that is not affected by environment (7).

A closer study of the cane plant with the purpose of correlating visible characteristics with high sugar yield should be made.

Every effort is being made to secure hybrids this year, with varying combinations of H 109, Lahaina, D 1135, Yellow Bamboo, Striped Mexican, Uba, Striped and Yellow Tip and Yellow Caledonia and the Uba Hybrids (12).

As yet no hand pollinization has been practiced (12).

D 1135 appears to be the most favorable stock from which to secure naturally fertilized seed on account of its very receptive female organs and being a heavy pollen forming variety (12).

In case of hand pollinated material, H 109 and Lahaina are found to be the most favorable female parents, while D 1135 and Badila are the best male parents (12).

In cases where both parents are known, the male parent appears to be the most prepotent for the characters sought to establish (12).

No factorial analysis of hybrid progenies has been attempted here to determine the application of the Mendelian law (12).

Seedling work will beyond doubt bring in more promising results in the improvement of our present varieties and strains of sugar cane and in a shorter time than bud selection (12).

In bud selection, progressive selection does much to improve the yields in the shortest possible time, but no further progress above a certain mean is possible through this method of selection (12).

Mutations and type mutations require more experience than any other line and an actual acquaintance with the variety in question. The resulting mutations are pure-line strains of the variety in question, which, if above the general run of the progenies in question, are of vital importance to the progress of bud selection and the improvement of sugar cane. This phase in the improvement of cane requires an actual acquaintance with the types of cane and a longer time to test out the pure line strains and mutations in progeny plantings (12).

With regard to seedling work, hybrids will in all probability bring in the best results, for in this branch only varieties with desirable qualities are used to produce seedling or hybrids. This method does not bring in the numerous seedlings which are to be found with volunteer tassels. Volunteer tassels, however, serve the purpose of securing large numbers of seedlings, but a smaller percentage of desirable seedlings is derived from this source than from the hybrids. However, a greater variety of seedlings results from this source (12).

Self pollinated seedlings are not on the whole the best kind of seedlings for only the qualities of the parent are inherited by the seedlings (12).

Hand pollinated crosses are valuable as a source for deriving seedlings, but it is a more difficult means for securing seedlings (12).

QUESTION II. (a) 1. If you are raising cane seedlings (hybrids and or ''selfs''), what methods do you pursue in securing seed? 2. To what extent is hand pollinization practiced? 3. What parentage (variety) appears to be the most favorable stock from which to secure naturally fertilized seed? 4. And in the case of hand pollinated material which are found to be the most favorable female parents, and which the most favorable male parents? 5. In cases where both parents are known which appears to be the most prepotent for the characters sought to establish? 6. Have you attempted any factorial analysis of your hybrid progenies? If so, do the results appear to follow the Mendelian law? 7. From your experience and observation what methods of breeding, by bud selection (1—progressive selections, or 2—mutations); or through seedling work (3—volunteer seedlings, 4—hybrids, or 5—selfs, or 6—hand pollinization of selfs or crosses) do you consider the most favorable and promising for the improvement of our present varieties and strains of sugar cane? What appear to be the advantages and disadvantages of each of the different methods under consideration?

ANSWERS: (a) 1. Two methods—hand pollination and natural pollination. (The object of this question was to bring out the detailed technic of pollination.) (3)

From wherever good, naturally fertilized tassels can be obtained (4).

Seed is secured in the field on a large scale from natural hybrids or selfs of varieties desired as parents (7).

We have never raised cane seedlings (9).

Thus far just field collections have been made (12).

We have received practically all of our Field Test 1 seedlings from the H. S. P. A. Experiment Station. We do not produce any of the seedlings ourselves. We seem to get the best results from H 109 stock. The best seedlings that I have seen come from H 109 parent stock that has been crossed through wind pollinization from other nearby canes. This, of course, is a rather hit-or-miss proposition and I have no doubht that in the future the best results will be obtained from carefully worked out hand pollinization (14).

(a) 2. Hand pollination is resorted to when natural pollination is not possible (3).

Have not done any of this (4).

Only in an experimental way so far (7).

(a) 3. H 109, Lahaina, Striped Mexican, Tip canes, and Yellow Caledonia are considered to be the most favored stock for obtaining naturally fertilized seed (3).

Have not had enough experience with the different varieties to say definitely (4).

We prefer H 109 as the female parent (7).

Lahaina and H 109 (10).

H 1801 is outstanding as a variety from which to obtain numerous germinations, probably largely selfs. D 1135 is also worked freely both ways. H 109 has much less tendency to self. This also applies to Tip canes, Striped Mexican, Lahaina and Badila. So in order to obtain field crosses of these with D 1135 it is better to use D 1135 as the male parent, as one gets less selfs in that way (see chart) (11).

(a) 4. Uba as female. D 1135 and H 109 as male (3).

(a) 5. No decision has been reached on this point. Usually the seedlings of known parentage show more female characters than of the male character, and this preponderancy

may be due to a certain amount of selfing, and not due to the prepotency of the female cane (3).

No data (7).

Badila and Yellow Caledonia as female parents seem to be prepotent for high sugar content and vigor of growth respectively (11).

(a) 6. No (3).

No (4).

Carefully planned factorial analysis has not yet been attempted. In first generation Uba hybrids, the Uba characters predominate (11).

(a) 7. Progressive selections: Have no faith in the cumulative effect of bud selection practiced for a short time, but do believe in the repetition of selection for obtaining accuracy (3). On this point, Shamel, in *The Improvement of Plants Through Bud Selection*, p. 3, 1921, states: "The experience and observations of the writer have led him to believe that by continuous selection in isolated strains—[I take this to mean a comparatively fixed or pure strain.—F. G. K.]—the mean of the variation in the selected population may be raised to a point more nearly approximating the maximum exhibitions of the character in the strain."

Mutations: I feel this is the most important, but no method has yet been devised by which economic mutations can be spotted (3).

With the success of H 109 in mind it might appear that seedling work by the natural fertilization of selfs or hybrids offers the best opportunity for the improvement of our canes. On the other hand, when the fact is considered that no very distinct improvement over H 109, among the self-pollinated seedlings, that have been raised since the advent of H 109, it might be better to turn towards methods in which the various phases are under closer control (4).

Seedling work seems to have the greatest possibilities in the improvement of cane production, but bud selection will be necessary to maintain this increased production. Hand pollinization of selfs and the purification of characters, later combining the desirable traits, seems to be the most advantageous method to follow (5).

Seedling work produced our "mainstay," H 109, and we have every reason to believe that we should be able to duplicate the success secured in propagating this wonderful cane. To date no other method in Hawaii has brought forth a commercial cane. This does not mean, however, that we should not give all methods a thorough trial. It is a question whether plantations themselves are prepared to do very careful breeding work involving years of crossing and recrossing. There is no doubt that strenuous efforts at scientific breeding should be made by the Experiment Station as opposed to the "hit-or-miss" methods that are used in securing natural field crosses.

We believe that seedling work offers the best opportunity to obtain better cane varieties (9).

A good deal of work in improving corn has been done by taking two outstanding varieties and breeding pure strains of each. These pure strains were then crossed and the results were gratifying. It seems that this same method could be applied to cane. Naturally it would take some time to get results, but in the end they might easily pay all the expense and trouble incurred (10).

Seedling work has proven value. Bud selection has not advanced far enough to compare with it. The former has 20 years back of it and the latter 5 years. As we see it the two should go hand in hand. Seedling work to produce new varieties with new combinations of characters to meet the varying conditions, and bud selection mainly to keep up what we already have to its original standard. Bud selection in sugar cane is not creating anything new; it is trying to maintain and purify what we already have (11).

Volunteer seedlings are not advantageous, because they may not have the combinations sought, and they are not found when wanted (3).

Hybrids seem to have vigor of growth (3).

Selfs are too weak for immediate commercial purposes. They are valuable for studying heredity (3).

Hand pollination permits the crossing of varieties growing at a distance, but the method cannot be followed on a large scale on account of the labor involved (3).

QUESTION III. (a) 1. Please describe as comprehensively as possible the technique that you have adopted in your bud selection and seedling work for the development and establishing of better varieties and strains of sugar cane, including methods of keeping breeding records. 2. Have you plans for extending and improving your methods of cane breeding, and what do you consider the most important reform, if any, that should be inaugurated to better bring about the results we are all asking—the development of more productive and better varieties and strains of sugar cane for Hawaii than are now being grown, or that at least may take the place of the best sorts, should any unforeseen difficulty befall them?

ANSWERS: Bud Selection: Stools with many, uniform, vigorous sticks are selected, cut for seed, and planted. The resultant crop is cut, weighed and the juices are analyzed. The high sugar yielders are selected for further trial. The selection is repeated until satisfactory results are obtained. Sometimes ratoon crops are tested (3).

Seedlings: The desirable tassels are planted and when the resultant seedlings are about one year old, they are selected on the appearance only. The cuttings of the selected ones are planted to definite areas. From this point on, the seedlings are tested several times for their sugar yielding power, with due consideration being given to other characters. Often, ratoon and two-year old crop are studied (3).

Ordinary technique used in bud-selection and seedling work. However, last season's experience with mud press cake as a germination medicine for (cane seed) gave unsatisfactory results (5).

First Stage: Large and small stools of cane showing definite characteristics of stooling and habit of growth are picked up from as many varied conditions on the plantation as can be found. No systematic "combing" of fields should be practised or too many similar types will be secured and make the elimination process too difficult.

Second Stage: All these stools are cut and planted in an area of fairly uniform soil, water and climatic conditions and allowed to grow to maturity. They should then be cut and allowed to ratoon. Notes should be made on these progenies from the time of planting and a continually close study made throughout the whole plant crop and ratoon. Such things as earliness of stooling and type of stooling should be particularly noted.

Third Stage: When the first ratoons are a year old—or if you are not in a hurry and allow the first ratoon to go to maturity too, in the second ratoon, cut out the progenies that have shown up as being different or outstanding. These should then be extended, each as if it were a new variety. Further extension should have no stool selection within the progeny but well nurtured seed should be used in all cases. Types that have been noticed in the original planting as being quite different growing alongside of each other, are usually planted again in adjoining blocks to note if these type differences continue.

Fourth Stage: When sufficient planting material is available a "checker-boarded" experiment should be laid out using unselected seed as a check. The harvesting data from such an experiment should be conclusive enough to determine whether any improvement has been made over the average of the variety.

The most important reform in our methods of breeding better varieties should be a detailed study of the characteristics, desirable and undesirable, that are hereditary in each of our main varieties; the purification of these characteristics and their combination by hand pollinization (5).

Greater stress is being laid upon seedling work here on this plantation, every effort being made to secure as many of the seedlings propagated and to develop seedlings here. Seedlings derived here, and others received from elsewhere, are planted first in a lower irrigated seed plot to secure as much seed as possible for the greatest spread when planted in regular test plots. The practice is to cut the seed in the lower seed plot and transfer

to the regular test plot, where each seedling is planted in such a way that it can be easily harvested and flumed to the mill for weighing and juice test. This necessitates planting the seedlings in sections 50 to 60 feet apart, for flumes here are placed from 50 to 75 feet apart, depending much upon the tonnage of the field. This method insures quicker results on a larger and more accurate scale, all scaling in the field on a small scale, and all juice tests from small quantities of the varieties and seedlings being eliminated. This method brings results in three years, one year in the seedling plot and two years at the test plot (12).

Our nursery methods in the seedling work have not changed materially in the past season and are described in last year's report. The problem of selecting the canes is very difficult, and requires the most thorough investigation. There are two points which we stress, viz: (1) to have all varieties planted adjacent to H 109 checks so that real comparisons can be made, (2) to place more reliance on the results secured from ratoons than plant cane. Our program calls for a monthly inspection of all seedlings and notes are made on their appearance on specially prepared cards. At harvest cane weights are secured and juice sampled. In selecting as our standard H 109, we have aimed very high. We grow many varieties that seem good, but few that actually come anywhere near the "he-cane," H 109 (7).

We use the same method in testing both types of progenies. After the progeny or seedling has been selected it is spread out into line or two line plots with H 109 as a check between each of the tests. These go through to maturity and are hand scaled and juice samples taken. Any that equal or outyield the H 109 check in sugar are spread as rapidly as possible into watercourses of level ditch area so that data on actual field conditions may be obtained. This covers a period of about four years; one and a half years after first selection, one year later cut for seed, and 18 months later cut for crop to get actual yield (9).

The factor which governs our selection is "tons of cane per acre." (See additional valuable data in original letter.) (11.)

In both the bud selection and the seedling work, trustworthy results may be obtained if regular variety tests are given to those that have survived very severe selection.

See tabulation of inheritance of color, etc., in Uba x D 1135 cross (11).

The following are supplementary answers to the questionnaire. William Wolters states:

Regarding the questionnaire on Genetics and its Relation to Cane Production, I beg to state that we have as yet not done very much in that line of work in view of the fact that this department only started to function about a year ago. Most of the time has been taken to establish this department and get it on a working basis before real investigations and research could be handled.

I am most willing, however, to extend whatever information regarding the above named subject that I possibly can. I will give you a resumé of what has been done along this line of work, and hope you may find something of interest, if not of value. I trust you will not be disappointed to find that your questionnaire is not answered as completely and satisfactorily as might be expected for reasons already given.

Practically no breeding work in cane has been done on the plantation as yet. Cane selection work has been done in a very small way and mostly in seedlings.

I. Seed pieces from a fair number of seedlings have been received from the Hawaiian Sugar Planters' Association Experiment Station and planted out in the fields. They are planted under normal conditions and receive plantation care in the way of fertilization, irrigation, cultivation, etc. Observations are made from time to time to note external characteristics, habits of growth and effects of environmental influences.

At about the time of maturity the first selection is made in which poor showing seedlings are eliminated. In this selection a large number are thrown out—fifty per cent or

more. The selected ones are planted out again using the best seed. Again these seedlings are planted under normal conditions and receive plantation treatment.

This process of selection goes on until we have seedlings which can reasonably stack up against our H 109 crop cane as a standard. It is not desirable to have seedlings that show no sign of merit or prospects of being a good commercial cane occupy valuable land.

We have reached the point where we have six seedlings that may show some promise of being a good commercial cane, but are not sure until we have tested them on larger areas and under varying conditions, and have assumed more or less fixed characteristics. The next logical step to take, therefore, would be to test them out on larger areas. So far we have these same seedlings growing on different parts of the plantation. In our case it is too early in the game to state any notable effects on seedlings as a result of change of location other than soil, in which case they grow better where the soil is richer.

II. In addition to seedlings grown from seed pieces, we have a patch of land set aside primarily to accommodate potted seedlings as bred by the Hawaiian Sugar Planters' Association Experiment Station, and planted by them in these pots.

A new lot was planted out the latter part of May, 1925. Here they were spaced two feet apart in 35-foot furrows and properly staked according to crosses in series. They received regular plantation care as usual. After a year's time the best will be selected and planted out and receive numbers, that is, Waipahu No. 1, etc. It is understood that seed pieces will be cut and planted. Selections will be made from time to time to eliminate the worst ones until we have a few which will, or may, show merit enough to compare favorably with H 109.

It is evident that the chief aim is to develop a cane, or canes, that may equal, or better, H 109, and supplant it in case anything may happen to H 109. Therefore this is the procedure which is being followed at the present time until some other procedure is deemed to be better.

No work in progeny studies has been done other than to plant out twenty-one H 109 progenies in one of our fields from selections by A. D. Shamel down at Waipio Sub-station. These will be studied from time to time to note anything which may be of interest and informing. It can clearly be seen that no information can be given at this time.

Our primary requirements for a cane here on the Oahu Sugar Company's plantation is one that will give a high yield, ratoon well, resist disease and also be capable of substituting a crop cane variety in case of necessity. Consequently any seedling which does not meet all these requirements in a fair proportion is not desired.

By Y. Kutsunai:

I. (a) To obtain accurate data on the hereditary characters of the various varieties of cane used in seedling work for the purpose of combining desirable characters intelligently.

Characters sought are adaptability, heavy cane yields, good quality ratio, and high degree of resistance to diseases and injury.

(b) Selection is based on cane yield and the quality ratio. These two characters seem in general to be compensating. In case the cane is not weighed, the volume of the cane is judged. The weight and the volume are very closely correlated.

(c) Some of the hybrids have established improved lines to the extent that they are replacing the older varieties.

(d) 1. Rose Bamboo, Yellow Tip, Striped H 109, Striped Yellow Caledonias, Striped D 1135, White D 1135.

2. Do not know. More mutants were found in H 109 than in Yellow Caledonia, but this difference may depend on the relative amount of labor spent in looking for the mutants.

3. Do not know, but plant crop is preferred in selection work.

4. Do not know.

5. Do not know.

(e) 1. Progenies are given ample room to develop so that their relative capacities only become the limiting factor.

2. The data on bud selection are conflicting and need more time to decide this point.

3. The difficulty of detecting the invisible characters and the masking influence of the environment.

4. Detailed study of the cane plant with the view of establishing visible indices correlated with invisible characters may help in this.

II. (a) 1. Two methods—hand pollination and natural pollination.

2. Hand pollination is resorted to when natural pollination is not possible.

3. H 109, Lahaina, Striped Mexican, Tip Canes, and Yellow Caledonia are considered to be the most favorable stock.

4. Uba as female. D 1135 and H 109 as male.

5. No decision has been reached on this point. Usually, the seedlings of known parentage show more female characters than the male characters, and this preponderancy may be due to a certain amount of selfing and not due to the prepotency of the female cane.

6. No.

7. (1). Progressive selection. Have no faith in the cumulative effect of bud selection practiced for a short time, but do believe in the repetition of selection for obtaining accuracy.

(2). Mutations: Feel this is the most important, but no method has yet been devised by which economic mutations can be spotted.

(3). Volunteer seedlings are not advantageous because they may not have the combinations sought, and they are not found when wanted.

(4). Hybrids seem to have vigor of growth.

(5). Selfs are too weak for immediate commercial purposes. They are valuable for studying heredity.

(6). Hand pollination permits the crossing of varieties planted far apart, but the method can not be followed on large scale on account of the labor required.

III. (a) 1. Bud selection: Stools with many, uniform, vigorous sticks are selected, cut for seeds, and planted. The resulting crop is cut, weighed, and the juices are analyzed. The high-sugar yielders are selected for further trial. The selection is repeated until satisfactory results are obtained. Sometimes ratoon crops are tested.

Seedlings: The desirable tassels are planted, and when the resulting seedlings are about one year old, they are selected on the appearance only. The cuttings of the selected ones are planted to definite areas. From this point on, the seedlings are tested for several times for their sugar yielding power, with due consideration being given to other characters. Often, ratoons and two-year crop are studied.

2. In both the bud selection and the seedling work, trustworthy results may be obtained if regular variety tests are given to those that have survived very severe selection.

By the agricultural department of the Experiment Station, H. S. P. A.:

I. (a) The ultimate object of all cane breeding is to find varieties which under certain conditions of environment will produce sugar with greater profit than the so-called "standard varieties" hitherto grown. This result is obtained by either increasing production per acre, or with hardier canes, producing sugar at less cost per unit.

These conditions of environment are somewhat as follows:

1. Climatic conditions.

    Temperature (mean annual and extremes).
    Rainfall.
    Wind.
    Sunlight.

2. Type of Soil.
   Drainage.
   Fertility.
   Toxic elements.
3. Rodents and Insect Pests.
4. Disease Organisms.
5. Weeds.
6. Plantation Practice.
   Cultivation.
   Fertilization.
   Irrigation.
   Length of crop.

Whether a seedling will produce sugar with greater profit than the former standard variety is determined by its degree of adaptability to any given set of conditions. A single change in these conditions may necessitate a different variety of cane.

With the above mentioned object in view the work of the cane breeder can be divided into three parts: (1) Selection of parent varieties, (2) nursery work of growing the seedlings from the tassels, (3) selecting the better seedlings from the undesirable, (4) determining the variety most suited to any given environment.

Seedling work is, of course, endless since perfection can never be attained, and conditions always change.

1. (b) Selection is based on sugar yield, other factors being secondary. (So far no other character has been found that can be correlated with sugar content except possibly vigor of growth.)

(c) Several hybrid seedlings have been grown at the Station, which show decided improvement over former standard varieties. H 109 is now planted in place of Lahaina on the lowlands, and several Tip and Uba seedlings have been developed that may take the place of D 1135 and Tip canes on the upper fields. H 109 itself will probably very soon be replaced by its own offspring or those of Lahaina.

With bud selection improved lines have not yet been definitely established.

(d) 1. So far the only certain mutations have been those of color. Examples are: Striped H 109, Striped D 1135, Striped U D 1. Rose Bamboo has been observed as a mutation of Striped Mexican.

2. No definite data, both seem to show color mutations.

3. Not sufficient data for conclusions to be drawn.

4. This has never been determined here, at least.

5. The only known mutations are those of color, and these have not been definitely correlated with high sugar yield.

(e) 1. Our progeny tests are conducted in such a manner as to avoid if possible varying environmental influences. The plot chosen for progeny work must be practically level and the soil as uniform as is possible with Hawaiian soils. Only such seed is planted as will give even germination, since a good stand is an essential. Germination is often further controlled by first planting the seed in temporary boxes with removable bottoms. The sides of the boxes are widest at the bottom and narrowest at the top, so that when the cane is finally planted in the ground the bottom is withdrawn, and the sides can be lifted from the plant without disturbing the root system. An attempt has been made to avoid unevenness of light, aeration, and water by placing the plants in rows five feet apart from center to center, and using flumes in place of the ordinary watercourses. The amount of water given each plant is checked as accurately as the scope of the experiment will allow. (At Makiki the flow of water is regulated by stop watch.) In the case of the fertilizer this can of course be accurately apportioned to each stool. Plants bordering on the outside of the plot would have the advantage of more light and space, therefore their yields are not considered.

2. It is too early to state definitely that bud selection has resulted in the establishment of improved strains. One of our Yellow Caledonia progenies seems to have made a

very good record, but it must undergo further tests before its value is determined positively. It was six or seven years after its propagation before the superiority of H 109 was proven with any degree of certainty. Perhaps the reason people are too quickly becoming discouraged with bud selection is that everyone was a little too optimistic at the beginning.

3. The greatest difficulties of the work in hand appear to be:

(1) Inability to recognize mutations other than those of color.

(2) Practically impossibility of absolutely controlling environment.

4. Our present method of planting the cane in holes spaced five feet apart is our latest attempt at controlling environment. We must, of course, continue our efforts along this line. A closer study of the cane plant with the purpose of correlating visible characteristics with high sugar yield should also be made.

II. (a) 1. Two methods: (1) Natural crosses in the field, (2) Hand pollination.

2. Hand pollination is practiced (1) when it is impossible to obtain natural crosses, (2) in order to have more definite knowledge of parentage.

3. H 1801 is outstanding as a variety from which to obtain numerous germinations, probably largely selfs. D 1135 is also worked freely both ways. H 109 has much less tendency to self. This also applies to the Tip canes, Striped Mexican, Lahaina and Badila. So in order to obtain field crosses of these with D 1135 it is better to use D 1135 as the male parent, as one gets less selfs in that way. (See appended chart.)

4. In the case of hand pollinated material definite statements can not be made. At the Station, Uba has been found to be a good female parent, but without more data on this point comparisons should not be made.

5. Badila and Yellow Caledonia as female parents seem to be prepotent for high sugar content and vigor of growth respectively. This subject has not been critically studied as yet.

6. Carefully planned out factorial analysis has not yet been attempted. In first generation Uba hybrids, the Uba characters predominate.

7. Seedling work has proven value. Bud selection has not advanced far enough to be compared with it. The ratio of their ages here is as 20 is to 5. As we see it, the two should go hand in hand. Seedling work to produce new varieties with new combinations of characters to meet varying conditions, and bud selection mainly to keep up what we already have to its original standard. Bud selection in sugar cane is not creating anything new. It is trying to purify what you already have.

III. 1. Every stool is carefully examined, and data is recorded as to disease, insect infestation and injury, rat damage, mechanical injury, etc. In some tests juice analyses are made. The number of stalks in each stool is noted, and their uniformity recorded. The stools are weighed and the heaviest in the higher yielding progenies are then selected for new progeny tests. From these heavy stools only the best seed is chosen, and planted in boxes. Those plants which seem to have germinated best are transferred to test plots, and planted in holes with even spacing. Those plants which were poor in germination are either discarded or used as protecting rows bordering the selected material.

The factor which governs our selections is "tons of cane per acre."

2. It is thought that by bringing in new varieties, such as Kassoer and the Java canes (now in quarantine), the scope of our seedling work can be broadened and the chances of obtaining desired crosses considerably increased. The idea being to produce hardy canes, thereby lowering cost of production.

There is also much to be done along the line of determining what characteristics are transmitted to their offspring by the different cane varieties. This will enable us to decide which parents will give the best crosses for any given set of environmental conditions.

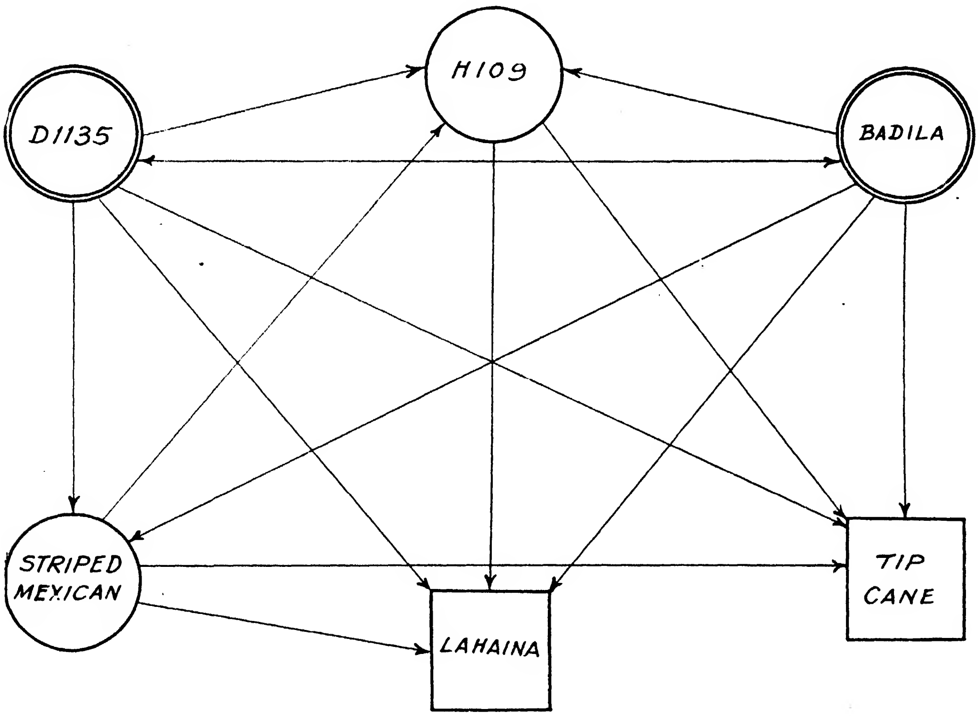
Lastly, the development of pure lines through inbreeding offers great possibilities for seedling work of the future.

INHERITANCE OF VARIOUS CHARACTERS IN THE UBA X D 1135 HYBRIDS

The Uba x D 1135 hybrids seem for the most part to resemble the female parent, Uba, rather than D 1135. Any one at all familiar with the parents receives this impression after even a hasty inspection. It is, however, very difficult to put this impression down in the form of exact figures. The following data have been compiled from rather careful descriptions of the seedlings on file at the Station. The personal factor for such characters as color and hardiness of rind is rather too great to attach very much importance to this tabulation.

DIAGRAM SHOWING DIRECTION OF POLLEN TRANSFER IN SUGAR CANE CROSSES

Arranged from data obtained in study of cane flowers and field observation of hybrid canes—Season 1924-1925



Double circle = Self fertile flowers. Circle = Slightly Self fertile flowers. Square = Self sterile flowers.

Color. In the case of color any hybrid with even a small amount of purple, red, pink, bronze or brown was thought to show a tendency toward D 1135. The others, which were colored green, gray green, yellow green, or yellow were classed as showing Uba characteristics.

Uba coloring	70
D 1135 coloring	41
	111

Hardness of Rind. The fact that Uba has considerably harder rind than D 1135 served to again classify the seedlings.

Uba	76
D 1135	26
Doubtful	9
	111

Eyes. Uba eyes are prominently pointed, so much so that they generally pierce the leaf sheath. There is also a marked tendency to lala. D 1135, on the other hand, has flat, round eyes that seldom lala and never pierce the leaf sheath.

Uba type eye	49
D 1135	47
Combination	10
Unclassified	5
	111

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Professor of Agronomy, The University of Hawaii

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Most of these works contain extensive bibliographies which may be consulted for further study. See especially, Castle's Genetics and Eugenics, 3rd Ed. (4).

The Control of Irrigation Water*

(*Published in Abstract*)

By J. M. Watt

The Purpose of Measurement

There may be several purposes for the measurement of the irrigation waters on plantations. When a definite policy of irrigation has been decided upon through observation and research, the measuring of water will be confined to the measurement of the supply, the measurement between sections, the measurement to the

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

field, and ditch seepage losses from which the balance of the daily supply is obtained.

In the early stages of work, before the point is reached where a water balance is available, measurement has necessarily to be carried on along several other lines, and this is the stage of the work that most of the plantations are concerned with at the present time. These are for purposes of investigation and observation.

In the first place all waters coming onto the property ought to be measured in order to arrive at accurate cost figures relative to supplies.

The plantation is generally divided into sections under the jurisdiction of section overseers. Some of these sections require more or less water, depending on the nature of the soil, conditions of environment, nature of the fields, age of the cane, and other factors that may complicate the problem. This water should be carefully measured so that the right amount will go to the right place at the proper time. In this way difficulties due to shortages and oversupply may be avoided.

It is of importance to have measuring devices at the head of each field so that the section overseer can distribute his total supply in an intelligent manner. In this manner it is a very easy matter to know at any time exactly what has been taking place within the field from the time of the last harvest.

To arrive at the maximum duty of water so that a water balance may be created, it is necessary to carry on experiments to determine the response of the cane to treatments that are favorable or unfavorable. In this work, ditches within type fields should be selected and different treatments applied. By the variation of practices throughout these, the water requirement for a given treatment is available at the conclusion of the experiment. It is through measurements of this kind, carried on with measurements of total water applied to fields of varying types that the duty of water may be found. Then, by knowing what should be done, and also what has been done, which is only obtainable through records of field runs in the past, errors in judgment and practice can be detected, and proper methods applied. At such a time, and at no other time can an intelligent balance be applied.

Experiments of varying kinds are possible to determine the cane response to water application. The first of a series which has been carried on for the past two years is called the Regulated Irrigation Experiment; in this type of experiment several ditches are selected within fields of as many varying types and cropping systems as possible, enough ditches being selected to allow for practice repetitions if possible. In each ditch, preferably at the head or intake of the ditch, a measuring device should be installed to record water applied. Then the special practices are determined in an arbitrary manner at first as there has been nothing of the kind previously done upon which to base policies. A minimum treatment is scheduled in which the cane is irrigated at intervals which will in no way allow for an excess of irrigation. A normal treatment is then scheduled in which it is felt that the cane is irrigated at the best possible interval, and in the third or maximum treatment the intervals are so scheduled as to give the cane all the water that it can possibly use. Against these, check ditches are provided in which the irrigation follows the practice of the remainder of the field which is irri-

gated as the overseer gets to it in the course of his rounds. In each instance as nearly as possible the same amounts of water per man are applied to each plot per irrigation.

From the results of an experiment of this nature upon harvest the practice favorable to a given type of field is indicated. If the limits have been too drastic or too wasteful, these are either drawn in or extended as the case may be. The practices applied for each treatment are similar in each type of field.

A second series of experiments in which ditches and measuring devices are selected in the same manner is called the Winter Cane Growth Experiment. In this case, treatments or intervals of irrigation are varied in the winter or cold months alone, with constant irrigation intervals throughout the summer or good growing months when cane growth is at its best. This type of experiment will show the amount of water or irrigation interval that is preferable in winter to give the best growing conditions. It is a very easy matter to apply too much water in winter, and this experiment is aimed at such a practice.

A third series is called the Summer Cane Growth Experiment; the experiment is similar to the one last mentioned except that the winter interval is constant, the variation being in the summer interval to determine the best practice for summer growth in fields of varying types.

A fourth series is the Cane Ripening Experiment. It is a general practice on the plantations to take water off the cane sometime before harvest, depending on the nature of fields. In this experiment several ditches of a similar character are selected and the time that water is to be taken off is decided upon. Here the ditches are grouped, some being carried on to the period of final irrigation at the normal field rate, while others have the interval of irrigation extended gradually for about five months before the time of final irrigation. In this manner sucrose response and cane growth are observed in all ditches. The practice that gives the greatest sucrose content and lowest cane tonnage per acre is the one that is to be desired.

By carrying on experiments of this nature the best practices to follow can be determined and through a combination of these results the best general practice can be provided for. This will show the maximum duty of water in sugar production per acre, so that a definite water balance may be created and maintained throughout a given plantation.

Other experiments may be carried on to decide upon favorable practices such as the water requirement in hilling up as against non-hilling up with the resultant sugar yield, experiments determining the value of long line irrigation as against regular contour irrigation, various forms of plowing, various methods of applying water to the furrow, various lengths of watercourses and number of lines between ditches, or any number of other practices that may be tested.

It is only through work of this nature that we can obtain correct information, correct poor practice, and place irrigation on a sound basis. Fertilizer problems were gone at in this manner, and the same can be done with our water problems.

Soil Moisture Determinations.

The determination of soil moisture depends entirely on the nature of information that is desired.

The main value of this work is in studies of the retention capacities of soils, depth of percolation of water in soil types, or variation of the latter in soils of the same nature under varying conditions.

Soil moisture determination work is very laborious, expensive, takes a great deal of time, and the value of it ought to be very clearly estimated before it is gone into on a large scale.

Cane Growth Measurements

The growth of cane is varied by a great many conditions. Taking measurements under these conditions enables keeping a continuous record of crop progress. These measurements can also be applied in general practice to get a comparison of cane growth from year to year over different or successive crops and cropping methods.

They are, however, of little or no value unless enough of them are taken to insure average figures, as variation within a field or plot of cane is known to be considerable.

In each plot or ditch at least five locations should be selected, and within each location no less than five sticks should be measured to insure relatively good average figures. Measurements of elongation should be accompanied by measurements of diameter, or preferably of circumference to obtain volumetric measurement to determine the total quantity of cane on the ground. For special work, more measurements may be taken over given plots. In general field work, five locations of five sticks each at least are necessary to enable drawing reasonably accurate conclusions.

Measurements should commence early in the life of a field to indicate every possible response or change of growing conditions. Measurement of growth may be started from two to three weeks after the cane is harvested in some instances and carried on to the time of maturity.

These measurements require an immense amount of work and the sheets upon which the data are collected rapidly become voluminous, so that it is a good policy to have the averages of growth and diameter systematically carried forward on filing cards where they may be studied.

Measurements of growth may be taken at periodic intervals or at given intervals of irrigation. In the latter the response in growth to a given application of water is readily obtained and has been found in many cases to be the best practice. This method is favored, although it takes a great deal more time.

These measurements may be taken to bring out several very interesting points such as periodic growth of cane, growth in relation to seasonal variation, growth in relationship to the age of the cane, and cumulative growth with varying experimental treatments applied.

Men should be selected for this work who are interested in it, diligent, and accurate, as it is tedious and hard work, especially when the cane is big and the stand heavy.

Juice Sampling

Periodic sampling of cane juice prior to harvest is of value in many instances, as it will show the varying condition of cane in a field and often serve as a guide in taking off a field at the most advantageous point.

In experimental work, it is of great value as it allows a person to study the response of the sucrose content with respect to water treatments before the field is harvested. It can be carried on in conjunction with growth measurement work to show the correlation between growth water application and juice condition.

This work is not reliable unless a great many samples are taken; it is tedious and laborious work and requires most exacting efforts to be of value. Samples should be taken over many locations and where special influences do not affect the juice.

All such data as they become voluminous ought to be averaged and filed on cards for ready reference and study.

Overhead Irrigation

Irrigation of sugar cane by means of the overhead application of water is a relatively new venture in the Hawaiian Islands.

The method was developed at Hawi Mill & Plantation Company by Mr. Hind, and is known as the Hind System of Overhead Irrigation. It has worked very well, and through the application of this system higher cane yields have been obtained than ever before upon the same lands.

The water is applied by the use of a number of sprinkler heads mounted on riser pipes at a height, and spaced at distances, depending on surrounding conditions. The water can be obtained from gravity flow, or it may be supplied from a pump that will give the required pressure for proper operation of the system. One method works as well as the other.

Before the installation of such a system it is advisable to lay out some experimental standpipes to determine the required pressure, the size of the pipes needed, the range of throw of the heads, particularly under varying wind conditions, as the spacing of other installations in general will not be a satisfactory guide.

By actual comparison with contour plots separated from the sprinkler areas by buffer plots so that one will not be affected by the other, it has been observed that the stand of the cane and appearance is equally good. Actual germination and stalk count after a period of six or eight months showed that the sprinkler plots were in the lead. The cane is as thick in one as in the other.

A three-inch application will penetrate the trash blanket of one-hundred-ton per acre cane and penetrate the soil to a depth of two or three feet, which shows that the system can be used with heavy cane.

Some of the main advantages of the system are that the soil or field is more easily prepared for planting; the expense of moldboarding is eliminated, as a shal-

low furrow is all that is required, a good soft seed bed for the cane to start in; the elimination of land required for watercourses and ditches as in contour irrigation; a great saving from the standpoint of labor required to produce cane; a uniform distribution of water throughout the area, absolute control of the water that is applied to the land; a good means of fire protection; and by better control of irrigation the sucrose content of the cane may be brought to a higher point through control of ripening. Irrigation can be carried on either by day or by night as desired.

Some of the disadvantages of the system may be the high cost of installation, difficulty in application of second season fertilizer when the cane is high, the possible rise in the salt content of the soil, and the increased growth of weeds in plant cane when the entire area is exposed to water. The real disadvantage of these points has not been proven to the point of condemnation.

SUMMARY OF REPLIES RECEIVED IN ANSWER TO QUESTIONNAIRE SENT OUT IN CONNECTION WITH "MEASUREMENT AND CONTROL OF IRRIGATION WATER."

1. Eight plantations are measuring irrigation supplies received.

2. Sources of water. Artesian and mountain.

3. Standard rectangular weir with bottom and side contractions, and water stage recorder is most satisfactory method of measuring mountain water.

4. Water stage recorders used are Gurley and Stevens "E" and "L."

5. Pumped waters are measured by weirs at discharge end of pipe. Venturi meters at pumps, displacement, current meter measurements.

6. Measurements are used for distribution of costs over fields, determination of irrigation per acre and per man day, determination of seepage losses and duty of water.

7. Irrigation policy is controlled and water distributed according to field demands and irrigators available, using data to prevent waste and to encourage light applications.

8. Four plantations actually measure water as applied to land.

9. Advantage of field measurements—clear knowledge of field requirements, to determine duty of water and enabling creation of a water balance, knowledge of whether water is being used efficiently, determination of seepage losses.

10. Water required per acre per irrigation, man days required per acre, and water requirements of various soils in different seasons of the year are being determined by five plantations.

11. These measurements are, first, for the purpose of obtaining the maximum duty of the present supply of water, and, second, to determine what supplies should be developed to profitably irrigate areas now available.

12. The amount of water required to make a complete irrigation of each field is being measured by four plantations.

13. The object of this measurement is the creation of a water balance, through the determination of the duty of water for the various lands of a plantation, and to enable distributing water to the best advantage.

14. Duty of water experiments are now being conducted on five plantations.

15. These consist of regulated irrigation experiments, seasonal cane growth measurements, cane ripening experiments, and comparisons of different types of irrigations, to determine correlation of water, temperature and growth, the ultimate object being the maximum duty of water.

16. Actual growth measurement of growing cane is reported by seven plantations.

17. Soil moisture determinations are not of much value due to varying saturation within a given location (as, for example, the top and bottom lines of the same watercourse). They do, however, determine how far down irrigations are affecting soil moisture.

18. Juice sampling is carried on in all investigational areas on one plantation from seven to eight months before harvest to the actual harvesting of the field, to show change of condition of the cane.

19. The correlation between measured water, soil moisture content, juice condition prior to harvest, and growth measurements varies with locality or soil type, but is expected to be of the greatest assistance from a practical standpoint.

20. Eight plantations report that the division of water between sections of the plantations is facilitated by the proper measurement of water.

21. This enables making a more equitable distribution of the water available at the different sources; serves as a check on the efficiency of irrigation applications; and determines the variation with locality and soil type.

22. Measuring equipment used includes weirs, Great Western Meters (submerged orifice type), Gurley Stage Recorders, Stevens Stage Recorders, Gurley Current Meters, Venturi Meters, Reliance Meters, Watson Water Stage Recorders.

23. The policy of measurement of irrigation water is favored, as it is a true basis for reliable information regarding duty of water, a water balance, the proper and most useful distribution of supplies; the basis of determination of future needs, determination of amount of water each man can handle efficiently, and enables changes in practice which will increase yield and cheapen cost of production.

24. Plantations now carrying on this work intend to increase the scope—several others are inaugurating the work.

25. The Hind Overhead System—Opinion is that it appears to grow good cane, saves labor, allows positive irrigation in definite amounts with equal distribution of water, cuts down ditch seepage losses; is advantageous in irrigating young plant and young ratoons where light and more frequent irrigations are required.

Possible bad features are fertilizer applications to big cane, and initial cost of installation.

Methods in Statistics*

By J. S. Donaghho
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All of our measurements are subject to error, so we always have to decide what value to accept from a given set of measurements, and what degree of confidence to place in the accepted value. The method of resolving these doubts is based upon the theory of probability. The reasoning employed in establishing this theory is based upon the assumption that all the separate events in any number of them under consideration are equally likely to occur. In practice, of course, this assumption will not hold completely, as a rule, so care must be taken that data

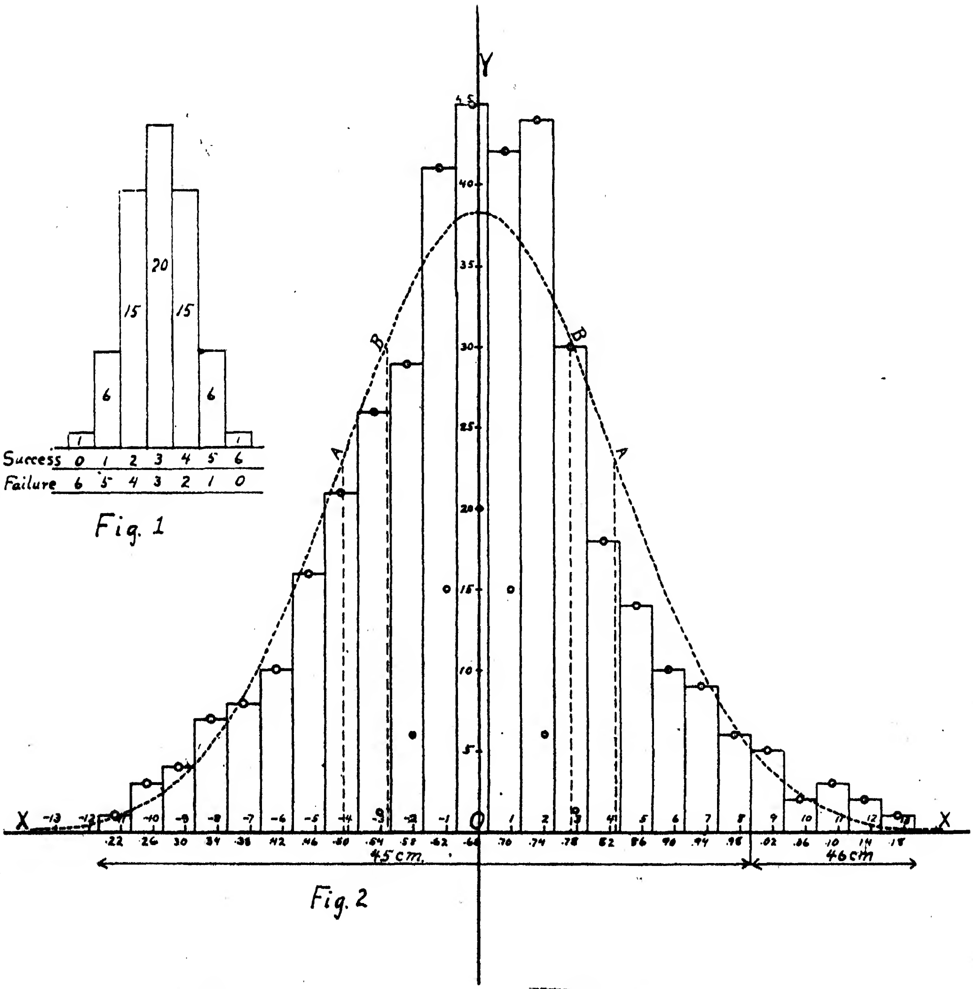

Fig. 1

Fig. 2

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

analyzed are adequate in number, and so chosen as to be typical of the larger masses to which the conclusions are to be applied. To be more specific, when conclusions are to be drawn from the study of a sample, and then applied to the large collection from which the sample was drawn, it is of vital importance that the sample should contain enough individuals so that the variations within it are likely to be about the same as those within the original collection, and especially that the sample should be taken at random—that even an unconscious selection of any particular type of individuals should be avoided, if possible.

The rectangles of Fig. 2 form a "frequency distribution polygon," showing the results of 397 measurements, by several successive classes in mathematics, of a supposedly spherical slated globe. The measuring apparatus consisted of a good meter stick, graduated to millimeters, a pair of wooden compasses, with which a circle could be drawn upon the globe, then transferred to a blackboard, measured, and the diameter computed from the result. In the figure the heights, or, as the bases are the same, the areas, of the rectangles show the number of values of the variable which fell in the interval indicated at the bottom. The figure at the bottom of a rectangle (below OX) denotes the middle of the interval. Thus, the interval marked 45.54 cm includes all measurements that fell within the interval 45.52 cm to 45.56 cm, including the former, and excluding the latter. This rectangle has a height, or area, of 26 units, since 26 of the values fell within that interval. The values of the variable (diameter of the globe) ranged from about 45.20 cm to about 46.20 cm, as is shown on the scale below OX. This range of 1 cm, more than 2 per cent of the total diameter, might tend to rouse our suspicions, were it not that so few results fell near the extremes, about the same proportion at the upper extreme as at the lower, while the great mass of the results fell near the middle of the range. Finally, the most important consideration, there is no known reason, aside from this suspicion, for rejecting one measurement rather than another.

Without any theory to work upon, we might lean toward 45.68 as a good value to accept, since more than half of the area of the polygon, that is, more than half of the measurements, fall within six rectangles, three to the right, and three to the left of this value. This method, however, might not assign enough weight to the rest of the results, farther to the right and left. It might be better to find the point where an ordinate (line parallel to OY) would have to be erected to bisect the area of the polygon. This point on OX, or this value of the variable, is called the median. The total area of the frequency polygon is 397, so we are to find the position of an ordinate that would have an area of 198.5 units on each side. Turning to the data for Fig. 2, and summing the frequencies (column "f"), from the top down, we find that those down to 41 sum up 166. Adding the next one, 45, we have 211. As 198.5 lies between these sums, we see that the required ordinate passes through the rectangle whose base is 45.64 to 45.68, and whose area is 45 units. Deducting 166 from 198.5 we have 32.5, the area within this rectangle that must lie to the left of the median. This is 32.5/45 or 0.722 of the whole rectangle. As the base of the rectangle represents 0.04 cm, we multiply 0.04 by 0.722, which gives 0.029 cm. Adding this to 45.64, the left end of the base, we get 45.669 as the median value, or the point on OX where an ordinate would

have to be erected, to bisect the frequency polygon. As we shall find, for this set of measurements, this is very near the vertical axis, OY, which passes through the value of the arithmetic mean.

By exactly the same method, we find that the ordinate at 45.524 will bisect the left half of the polygon, and that one at 45.761 will bisect the right half. These points are called the quartile values. The space between these ordinates is one-half of the area of the frequency polygon, and the interval between them represents 0.237 cm, so the quartile values show us that one-half of our measurements fall within a range of 0.237 cm, thus throwing some light on the accuracy of our set of readings.

By reasoning that cannot be introduced here, the theory of probability has proved that the most probable value from a set of results like this is the arithmetic mean of the whole set. This would be obtained by summing up all the values, and dividing by the total number of measurements. But as several other rather involved computations have to be made from the same data, the work of all is greatly abbreviated by first throwing the data into a convenient number of equal classes. The size of the classes is determined by considerations depending upon the nature of the material in hand, but one precaution may be noted here: the classes should be large enough so that every one will have at least one item in it. Following are the data for Fig. 2, with a brief statement of the method of computation:

DATA FOR FIGURE 2

m	f	d	v	fv	fv2
45.22	1	—0.48	—12	— 12	144
.26	3	—0.44	—11	— 33	363
.30	4	—0.40	—10	— 40	400
.34	7	—0.36	— 9	— 63	567
.38	8	—0.32	— 8	— 64	512
.42	10	—0.28	— 7	— 70	490
.46	16	—0.24	— 6	— 96	576
.50	21	—0.20	— 5	—105	525
.54	26	—0.16	— 4	—104	416
.58	29	—0.12	— 3	— 87	261
.62	41	—0.08	— 2	— 82	164
.66	45	—0.04	— 1	— 45	45
.70	42	0.00	0	0	0
.74	44	0.04	1	44	44
.78	30	0.08	2	60	120
.82	18	0.12	3	54	162
.86	14	0.16	4	56	224
.90	10	0.20	5	50	250
.94	9	0.24	6	54	324
.98	6	0.28	7	42	294
46.02	5	0.32	8	40	320
.06	2	0.36	9	18	162
.10	3	0.40	10	30	300
.14	2	0.44	11	22	242
.18	1	0.48	12	12	144
	397			Neg. 801	7049
				Pos. 482	

Probability Curve

x	y
0	38.23
1	37.14
2	34.03
3	29.41
4	23.99
5	18.45
6	13.39
7	9.17
8	5.92
9	3.61
10	2.07
11	1.13
12	0.56
13	0.28

The figures under **m** show the classes into which the measurements have been thrown: thus, class 45.58 includes all results from 45.56 to 45.60, including 45.56, and 29 measurements fell within that interval, as may be seen under **f**, that is, in the "frequency" column. Under **d** we have the deviation of each class under **m** from an assumed mean of 45.70 cm. Column **v** is obtained by dividing the corresponding items of column **d** by 0.04 cm; hence it shows, for instance, that class 46.06 has a deviation 9 times 0.04 cm from the assumed mean of 45.70. In practice, of course, it is not necessary to write column **d** at all. Simply write 0 opposite the assumed mean, —1, —2, —3, etc., in order above it, and 1, 2, 3, etc., in order below it. Column **fv** is obtained by multiplying items of column **f** by corresponding items of column **v**; it shows that the 2 measurements of class 46.06 have a total deviation of twice 9-times-0.04-cm, or 18 times 0.04 cm. The negative items in this column total 801, the positive items total 482, and the difference, negative 319, shows that the total deviation of the 397 measurements was negative 319 times 0.04 cm from the assumed mean of 45.70 cm. Multiplying 0.04 by 319, and dividing the product by 397, we get negative 0.032 cm as the average deviation, which deducted from 45.70 gives 45.668 cm, the mean of the 397 measurements. Column **fv**^{2} is obtained by multiplying items of column **fv** by corresponding items of column **v**. The sum, 7,049, is divided by 397, giving 17.76, the average of the squared deviations. As these are deviations from the assumed mean, the correction, 0.032 must be applied. It is first divided by 0.04 to reduce it to the same unit as the average. The result 0.8 of the class interval, is squared and deducted from 17.76 giving 17.12, a close approximation to the square of the deviations from the actual mean. The square root of 17.12 is 4.138, the "standard deviation." By the much more laborious method of obtaining **fv** and **fv**^{2} as deviations from the actual mean, the standard deviation turns out 4.143, showing that the approximation is very close. (The assumed mean must not differ greatly from the actual.) The smaller the standard deviation, the better the set of readings.

We must now seem to abandon the matter in hand for a while, in order to make clear what follows. That we may deal with events which are as nearly as possible equally likely to occur, let us suppose a coin tossed three times in succession, with the object of throwing as many heads as possible. Counting a head as a success, a tail as a failure, we see that three failures may fall out in just one way, that is, three failures in succession. So, also, three successes can occur in just one way. But two failures and one success can fall in three ways: (1) first toss a success, the rest failures, (2) second toss a success, the rest failures, (3) third toss a success, the rest failures. In the same way, two successes and one failure can occur in just three different ways. Thus we see that there are eight possible ways for the coin to fall, but only four possible combinations of success and failure. So the probability of three successes, or three failures, is one-eighth, that of two successes and one failure, or two failures and one success, is three-eighths. The sum of these four probabilities is 1; that is, one of these combinations is certain to happen. Fig. 1 is a graphic showing of the possibilities when a coin is tossed six times. The seven possible combinations of success and failure are tabulated in the two rows at the bottom. By reasoning exactly like

that given above, it can be shown that the coin may fall in 128 different ways, and that the distribution of the ways among the different combinations is 1, 6, 15, 20, 15, 6, 1, as graphically indicated by the areas of the vertical rectangles. Thus two successes and four failures may fall out in 15 of the 128 different ways, so the probability of that result is 15/128. Now if the same computations were made for 100,000 tosses, and the results plotted to the proper scale, we should have an apparently continuous curve, like the dotted one of Fig. 2, called the "probability curve."

The equation of this curve is $y = ae^{-kx^2}$, where **a** and **k** depend upon the values of the set under consideration. The method of deriving this equation is too difficult for insertion here, but an understanding of it is not necessary for the use of the equation. To find **a** for our curve, we multiply the standard deviation by 0.3989 and divide 397 by the product, giving 38.23. To find **k** we double the square of the standard deviation, and take the reciprocal of the result. For our curve we get $k = 0.02914$, so the equation of the probability curve for our set of determinations (showing the "normal distribution" of the results) is

$$y = 38.23e^{-0.02914x^2}$$

with the OY axis at the mean value, 45.668. Scale above OX gives x-values. To compute the quartiles, we multiply the standard deviation by 0.6745 which gives us 2.794. To get the equivalent in cm, we multiply this by 0.04, which gives 0.112 cm. That is, the quartiles are at that distance to the right and left of the mean, or at 45.78 and 45.556, respectively, thus differing slightly from the quartiles of the distribution polygon. The quartiles give us the probable error of a single reading; that is, the chance is even that a single reading will fall within 0.112 cm above or below the mean.

Dividing the quartile value 2.794, by the square root of 397, the total number of measurements, gives us 0.14, the probable error of the arithmetic mean. Its equivalent in cm is 0.0056, so we write the mean 45.668 ± 0.006. This does not mean that the true value lies between those limits, but that if another set of the same number of determinations were made, the chance is even that the mean of them would lie within those limits.

Let us now turn to the dotted curve of Fig. 2. If the number of readings for the various values had been according to the ordinates of this curve, the set would have had the same mean, with the same probability, as our original frequency polygon. Comparing polygon with curve, we see that the effect of the large number of values in the neighborhood of the mean has been neutralized, partly, by excesses at the extremes, and deficiencies near A, on the right, and to less degree elsewhere. If there had been a smaller proportion at the extremes, and a greater proportion near the mean, the curve would have been more steep and slender, the standard deviation and the quartiles would have been nearer the axis OY, the probable error of the mean would have been smaller. In short, it would have been a better set of readings. That is, *the steeper and more slender the curve, the better the set of readings.*

Let us suppose that the curve is the record of a large number of readings. Comparatively few of them fell near the value 45.20. The curve is concave upward from there to A, so we may infer that the number of readings for each

value increased, at an increasing rate, until A was reached. From A to the highest point the curve is concave downward, showing that the number of readings for each value increased, at a decreasing rate, throughout that interval. In the same way, the curve shows a decrease, at an increasing rate, from the highest point to A on the right, and a decrease, at a decreasing rate, from there on. The distance of A from OY is equal to the standard deviation.

DATA FOR SCATTER DIAGRAMS

Fig. 6		Fig. 7		Fig. 8	
X	Y	X	Y	X	Y
1.24	51.0	1.41	9.57	1.44	10.48
1.36	51.1	1.24	8.41	1.67	7.79
1.45	55.2	1.53	10.38	1.45	10.33
1.67	53.4	1.45	9.84	1.53	9.28
1.51	56.8	1.74	11.81	1.36	11.75
1.31	54.8	1.31	8.89	1.31	12.66
1.45	55.2	1.52	10.31	1.49	9.79
1.39	54.8	1.29	8.75	1.71	7.43
1.52	53.8	1.45	9.84	1.41	10.93
1.41	54.6	1.87	12.69	1.33	12.28
1.29	49.0	1.57	10.65	1.31	12.66
1.49	51.8	1.41	9.57	1.52	9.40
1.45	51.8	1.51	10.25	1.66	7.89
1.42	55.3	1.33	9.02	1.42	10.77
1.31	51.2	1.31	8.89	1.57	8.81
1.57	62.4	1.42	9.63	1.31	12.66
1.44	52.4	1.66	11.26	1.24	14.13
1.41	51.2	1.39	9.43	1.51	9.53
1.31	48.5	1.45	9.84	1.87	6.21
1.33	51.8	1.31	8.89	1.45	10.33
1.87	61.4	1.36	9.23	1.74	7.18
1.66	58.8	1.71	11.60	1.45	10.33
1.53	55.4	1.67	11.33	1.29	13.06
1.74	59.6	1.49	10.11	1.41	10.93
1.71	66.0	1.44	9.77	1.39	11.25

Figs. 3 to 8 are intended to furnish simple illustrations of correlation between data. Turn first to the data for Fig. 7. Column X may be taken to represent the lengths of small bits of wire, column Y the corresponding weights. Fig. 7 is called a "scatter diagram" of these data. Numbers in the two top rows, increasing toward the right, indicate the classes into which the Y data have been thrown; those in the first two columns, increasing upward, the classes of the X-data. In making the diagram, we note that the first item in the X-column belongs in the 1.40 to 1.47 class, the corresponding Y-item in the 9.40 to 9.89 class, so we put a score mark even with the first class, and under the second. For the second item we put a score even with the first X-class, under the first Y-class, and so for all the others. In the end the score marks form a pretty fair diagonal of the rectangle, and we infer a pretty close correlation—the bits of wire were probably almost uniform in diameter.

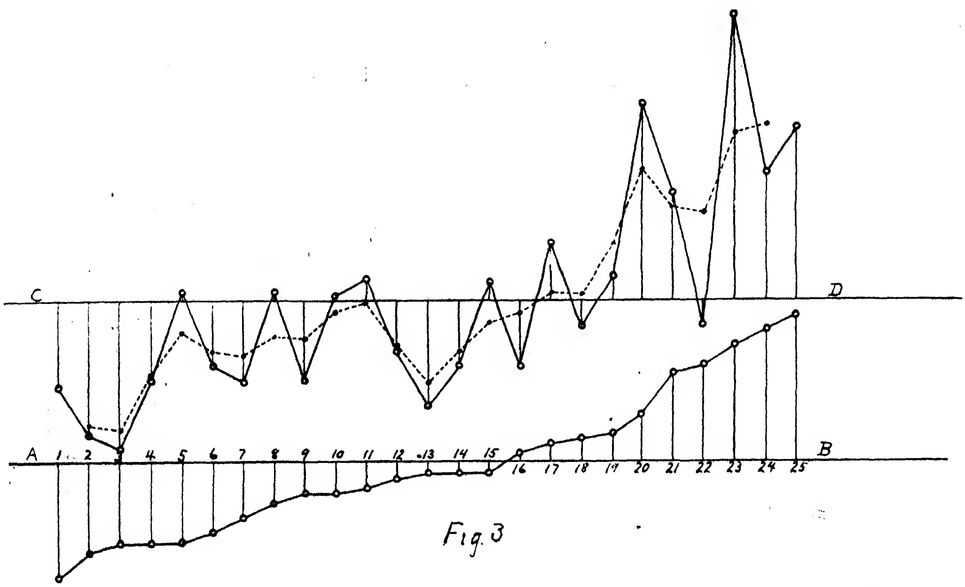
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Fig. 3

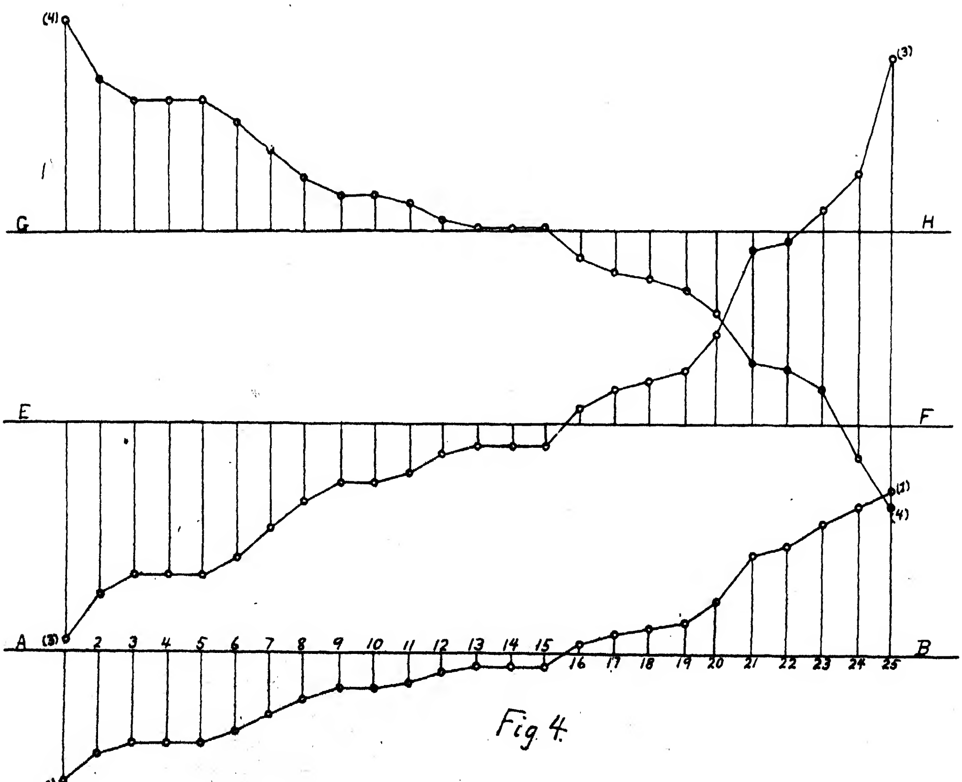
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Fig. 4.

		y		61	62	63	64	65	66	67	68	69	70	71	72	73	74											
		↓		61.9	62.9	63.9	64.9	65.9	66.9	67.9	68.9	69.9	70.9	71.9	72.9	73.9	74.9		y	f	fy	fy^2	$\sum x$		$\sum x$		$\sum xy$	
x	→			7	6	5	4	3	2	1	0	1	2	3	4	5	6						−	+	−	+	−	+
																			$\sum$	→	880	4100						
187	191	10									1	3	2	2	1				10	9	90	900		17		17		170
182	186	9								1						1			9	2	18	162	1	5		4		36
177	181	8											1	1			1		8	3	24	192		11		11		88
172	176	7									1	1	1	6	2				7	11	77	539		29		29		203
167	171	6									1	2	6	1	2	1			6	13	78	468		30		30		180
162	166	5		1						2	2	3	8	2	2	2			5	22	110	550	9	43		34		170
157	161	4							4	1	6	7	5	7	1				4	31	124	496	9	42		33		132
152	156	3						2	2	3	14	10	12	11		1	1		3	56	168	504	13	78		65		195
147	151	2						2	3	7	5	12	9	8	3				2	49	98	196	19	66		47		94
142	146	1						7	12	10	17	17	8	15	5	2			1	93	93	93	55	108		53		53
137	141	0			1		3	4	14	20	24	21	11	9	2		7		0	110								
132	136	1			2		4	9	18	18	17	8	8	4	3	1	1		1	93	93	93	109	59	50			50
127	131	2		1	1	1	7	7	11	15	16	18	9	5	2				2	93	186	372	104	59	45			90
122	126	3			1	4	2	12	17	16	14	4	5			1			3	76	228	684	120	19	101			303
117	121	4			2	2	10	9	6	6	7	2	2	2					4	48	192	768	107	12	95			380
112	116	5				2	7	3	3	3				2					5	20	100	500	56	6	50			250
107	111	6			3	1	5	2	1	1									6	13	78	468	52		52			312
102	106	7				1			2	3	1	1							7	8	56	392	12	1	11			77
			$\sum$															$\sum$ →			933	3277						2783
x	→		↓	7	6	5	4	3	2	1	0	1	2	3	4	5	6	↓										
f				2	10	11	38	57	93	106	126	109	87	75	23	9	4											
fx			744	14	60	55	152	171	186	106		109	174	225	92	45	24	669										
fx^2			2332	98	360	275	608	513	372	106		109	348	675	368	225	144	1869										

$\sum x = 669 - 744 = -75,\ d_x = \frac{-75}{750} = -0.1$

$\sum y = 880 - 933 = -53;\ d_y = \frac{-53}{750} = -0.071$

$d_x^2 = 0.01 \quad d_y^2 = 0.005$

$\sum x^2 = 1869 + 2332 = 4201$

$\sum y^2 = 4100 + 3277 = 7377$

$\sigma_x^2 = \frac{\sum x^2}{n} - d_x^2 = \frac{4201}{750} - 0.01 = 5.60 - 0.01 = 5.59$

$\sigma_x = 2.36$

$\sigma_y^2 = \frac{\sum y^2}{n} - d_y^2 = \frac{7377}{750} - 0.005 = 9.835 - 0.005$
$= 9.83$

$\sigma_y = 3.14$

$\sum xy = 2783$

$$r = \frac{\frac{\sum xy}{n} - d_x d_y}{\sigma_x \sigma_y} = \frac{\frac{2783}{750} - (-0.1 \times -0.07)}{2.36 \times 3.14}$$

$$= \frac{3.711 - 0.007}{2.36 \times 3.14}$$

$r = 0.5$

X-variable: Height of students in inches.
Y-variable: Weight " " " pounds.
Ohio State University.

Fig. 5

In the data for Fig. 8, column X may be taken to represent the length of various pendulums, column Y the corresponding number of beats in a given time. Plotted in a scatter diagram they give a close approximation to the downward diagonal of the rectangle, and we infer a rather close negative correlation—that is, an "inverse relation" between the length of a pendulum, and the number of beats in a given time.

Fig. 6 is the scatter diagram of the data for Fig. 3, and as the scores are rather scattered, but along the upward diagonal, we should infer an imperfect positive correlation. In Fig. 3, the same data are plotted, with the X-data arranged to increase toward the right, so that the curve never descends. The horizontal axis is not shown for either curve, the lines AB and CD representing the means of the X and Y curves, respectively. The general upward trend of the Y-curve indicates a certain amount of correlation, and the dotted curve through it, the result of "smoothing," shows it a little better. Each item of the original curve is averaged with the two items adjacent to it, to get the corresponding item of the smoothed curve.

DATA FOR FIGURE 3

	X	Y	d_x	d_y	d_xd_y		d_x^2	d_y^2
1	1.24	51.0	—0.234	— 3.48	+0.814	—0.000	0.0548	12.1104
2	1.29	49.0	—0.184	— 5.48	+1.008		0.0339	30.0304
3	1.31	48.5	—0.164	— 5.98	+0.981		0.0269	35.7604
4	1.31	51.2	—0.164	— 3.28	+0.538		0.0269	10.7584
5	1.31	54.8	—0.164	+ 0.32		—0.052	0.0269	0.1024
6	1.33	51.8	—0.144	— 2.68	+0.386		0.0287	7.1824
7	1.36	51.1	—0.114	— 3.38	+0.385		0.0130	11.4244
8	1.39	54.8	—0.084	+ 0.32		—0.027	0.0071	0.1024
9	1.41	51.2	—0.064	— 3.28	+0.210		0.0041	10.7584
10	1.41	54.6	—0.064	+ 0.12		—0.008	0.0041	0.0144
11	1.42	55.3	—0.054	+ 0.82		—0.044	0.0029	0.6724
12	1.44	52.4	—0.034	— 2.08	+0.071		0.0012	4.3264
13	1.45	50.2	—0.024	— 4.28	+0.103		0.0006	18.3184
14	1.45	51.8	—0.024	— 2.68	+0.064		0.0006	7.1824
15	1.45	55.2	—0.024	+ 0.72		—0.017	0.0006	0.5184
16	1.49	51.8	+0.016	— 2.68		—0.043	0.0003	7.1824
17	1.51	56.8	+0.036	+ 2.32	+0.084		0.0013	5.3824
18	1.52	53.8	+0.046	— 0.68		—0.031	0.0021	0.4624
19	1.53	55.4	+0.056	+ 0.92	+0.052		0.0031	0.8464
20	1.57	62.4	+0.096	+ 7.92	+0.760		0.0092	62.7264
21	1.66	58.8	+0.186	+ 4.32	+0.804		0.0346	18.6624
22	1.67	53.4	+0.196	— 1.08		—0.212	0.0384	1.1664
23	1.71	66.0	+0.236	+11.52	+2.719		0.0557	132.7102
24	1.74	59.6	+0.266	+ 5.12	+1.362		0.0708	26.2144
25	1.87	61.4	+0.396	+ 6.92	+2.740		0.1568	47.8864
	36.84	1361.9			+13.081	—0.434	0.5966	453.2060

In the table above are shown the computations for the "coefficient of correlation" for these same data. The column headed "d_x" contains the deviations of the X-values from the mean, that is, the lengths of the ordinates from AB to the

		48.1	50.1	52.1	54.1	56.1	58.1	60.1	62.1	64.1
		50.	52.	54.	56.	58.	60.	62.	64.	66.
1.80	1.87							/		
1.72	1.79						/			
1.64	1.71			/			/			/
1.56	1.63								/	
1.48	1.55		/	/	/	/				
1.40	1.47		///	/	///					
1.32	1.39		//		/					
1.24	1.31	//	//		/					

Fig. 6

curve, in Fig. 3. Column "d_y" contains the deviations of the Y-values, the lengths of the ordinates from CD to the curve. Column "$d_x d_y$" contains the products of the corresponding values in the "d_x" and "d_y" columns, part of them positive, part negative. The last two columns are the squares of the corresponding values in the "d_x" and "d_y" columns. These deviations have all been obtained by the longer method, finding the actual value of the mean, and then deducting it from the successive values of the frequencies. The work of substituting for the correlation coefficient is shortened, as we simply sum the last three columns, multiply together the sums of the last two, extract the square root, and divide the sum of the "$d_x d_y$" column by the square root. The shorter method is given in Fig. 5. The correlation coefficient for these data turns out $r = 0.770$. To find the probable error, subtract the square of **r** from 1, and divide the result by the square root of the number of measurements. The result is 0.020.

In Fig. 4 are shown plots of the data for Figs. 7 and 8. Curve (1) represents the X-data of both plots, curve (3) the Y-data of Fig. 7, curve (4) the Y-data of Fig. 8. It is apparent at a glance that the products "$d_x d_y$" of (1) and (3) would all be positive, while those of (1) and (4) would all be negative. For the former the correlation coefficient turns out to be 0.99984, with a probable error of 0.00004; for the latter it is —0.9956, with probable error 0.0018.

		8.40	8.90	9.40	9.90	10.40	10.90	11.40	11.90	12.40
		8.89	9.39	9.89	10.39	10.89	11.39	11.89	12.39	12.89
1.80	1.87									/
1.72	1.79							/		
1.64	1.71						//	/		
1.56	1.63					/				
1.48	1.55				////					
1.40	1.47			卌//						
1.32	1.39		//	/						
1.24	1.31	卌								

Fig. 7

Fig. 5 is a correlation table, to exhibit the correlation, and compute the correlation coefficient, of the height of 750 individuals, compared with their weight. The data, the method of arrangement, and the method of computation, are from "The Fundamentals of Statistics," by L. L. Thurstone, an exceedingly clear presentation of exactly what it claims to present. The body of the table is exactly like a scatter diagram, except that the frequencies are expressed as numbers, instead of as groups of score marks. In fact, the first step in making a correlation table must be to make something in the nature of a scatter diagram. At the bottom of the table is a row labeled "f." Each number in it is the sum of all the frequencies in the column above. The column enclosed in heavy lines contains the mean of these "fs." In the same way, in the column at the right labeled "f" each number is the sum of all the frequencies in the same row, and the row enclosed in heavy lines contains the mean. The rows labelled "fx," "fx²," "fy" and "fy²" are computed just as the corresponding columns were in the data for Fig. 2. A word may be acceptable, however, as to the columns after the "fy" column. The capital sigma in each heading means "the sum of," so the first two columns give the sum of the **x's**, positive and negative. To see how they are computed, let us turn to row 1, above the mean. On the negative side are 7, 12 and 10. Multiplying each by the number above it in the X-row at the top, and taking the sum, we have negative 55, which we find in the negative column of the sum of the **x's**. On the positive side are 17, 8, 15, 5 and 2. Multi-

		6	7	8	9	10	11	12	13	14
		6.99	7.99	8.99	9.99	10.99	11.99	12.99	13.99	14.99
1.80	1.87	/								
1.72	1.79		/							
1.64	1.71		///							
1.56	1.63			/						
1.48	1.55				////					
1.40	1.47					~~////~~//				
1.32	1.39						//	/		
1.24	1.31							///	/	/

Fig. 8

plying each of these by the number above it in the X-row, and taking the sum, we have 108, which we find in the positive column of the sum of the **x's**. The sum of these two results is positive 53, which we find in the second positive column of the sum of the **x's**. Multiplying this by positive 1, the corresponding item in the Y's, we have positive 53, in the column of the sum of the **xy's**. Below the mean, we have negative items in the sum of the **x's**, but they are multiplied by negative values in the Y-column, thus giving positive values for the sum of the **xy's**.

At the extreme right is a detailed statement of the computation for the coefficient of correlation **r**. The character occurring twice in the denominator of the formula for **r** is the small sigma, and is always used as the symbol for the standard deviation. The two factors in that denominator are the standard deviation for the **x's** and the standard deviation for the **y's**. If **r** equals 1, we infer perfect positive, or direct, correlation. If **r** equals —1, we infer perfect negative, or inverse, correlation. The value of **r** must fall between these limits.

TABLE NO. 1

VARIETIES OF CANE

	H 109	Y. C.	D 1135	Lahaina	Yellow Tip	Striped Mexican	Striped Tip	Rose Bamboo	Others
H. C. & S. Co.	94	..	1	1	..	3	..	..	1
Oahu	83	..	16	..	..	..	..	..	1
Ewa	100	..	..	..	..	..	..	..	..
Waialua	46	14	14	6	..	..	..	3	17
Pioneer	63	..	6	3	1	24	..	..	3
Olaa	..	88	11	..	..	..	..	..	1
Haw. Sug.	60	3	31	..	..	..	..	..	6
Maui Agr.	65	..	1	21	..	7	..	4	2
Lihue	37	55	2	..	1	..	..	..	5
Onomea	..	87	2	..	11	..	..	..	..
Hilo	..	96	3	..	..	..	1	..	..
Kekaha	39	..	13	44	..	..	..	..	4
Honolulu	75	20	4	..	..	..	..	..	1
Haw. Agr.	..	47	20	..	..	..	..	..	33
Hakalau	..	93	..	..	6	..	..	..	1
Wailuku	63	1	4	16	..	14	..	..	2
Makee	32	62	..	..	2	..	..	..	4
McBryde	50	42	5	..	..	..	..	..	3
Honokaa	4	4	82	..	3	..	3	..	4
Laupahoehoe	..	47	9	..	43	..	..	..	1
Pepeekeo	..	98	1	..	..	..	..	..	1
Hamakua	..	51	31	..	11	..	..	..	7
Kahuku	71	23	..	6	..	..	..	..	..
Paauhau	6	12	75	..	6	..	..	..	1
Honomu	..	97	..	..	1	..	..	..	2
Koloa	40	48	5	..	1	..	..	..	6
Hutchinson	..	54	6	..	..	..	..	40	..
Waiakea	..	98	1	..	1	..	..	..	..
Hawi	13	1	27	..	2	2	54	..	1
Kaiwiki	..	36	9	..	15	..	7	..	33*
Waianae	99	..	..	..	..	..	..	..	1
Kohala	..	20	42	..	13	..	22	..	3
Kilauea	20	22	9	..	26	..	1	..	22†
Kaeleku	..	100	..	..	..	..	..	..	..
Waimanalo	50	39	10	..	..	..	..	..	1
Union Mill	..	3	24	..	22	..	49	..	2
Halawa	..	27	6	..	..	..	67	..	..
Waimea	81	..	..	19	..	..	..	..	..
Olowalu	74	..	..	1	..	25	..	..	..
Niulii	..	35	8	..	15	..	42	..	..
True Average 1925.	42.7	30.8	11.9	3.1	2.7	2.0	2.0	1.0	3.8
" " 1924.	38.1	32.6	12.0	4.4	2.3	2.5	2.0	1.4	4.7
" " 1923.	30.7	36.3	11.2	8.4	1.2	3.1	1.6	1.5	6.0
" " 1922.	21.1	40.3	12.2	12.0	2.7	2.8	1.6	1.6	5.7
" " 1921.	15.0	45.1	11.0	17.4	1.2	3.0	1.8	1.0	4.5
" " 1920.	9.1	42.7	10.0	26.7	1.4	2.5	2.1	0.8	4.7
" " 1919.	6.8	46.4	7.2	29.1	0.3	1.8	2.6	2.1	3.7
" " 1918.	4.0	42.9	7.5	37.9	0.5	0.6	1.5	1.1	4.0

* Principally D 117.

† Principally Badila.

Annual Synopsis of Mill Data—1925

By W. R. McAllep

Reports have again been received from all plantations in the Association covering manufacturing operations from October 1, 1924, to September 30, 1925, during which time 776,196 tons of sugar were manufactured. This calendar year does not in all cases coincide with the crop year. Figures from four plantations, Haw. Agr., Hutchinson, Paauhau and Kilauea, represent portions of the previous crop ground subsequent to October 1, 1924. These four plantations and two others, Waianae and Honokaa, had not finished grinding on September 30, so data for the 1925 crop of these plantations are incomplete. Appropriate marks identify data from these plantations in the large table.

Data are presented in the same form as last year except that two of the tables, apparent boiling house recovery and molasses produced on the theoretical, have been combined. Factories are again listed in the order of the average size of the crop for the preceding five years, except in Tables IV and VIII.

More complete data transmitted to the Experiment Station for the revised mill reports have facilitated the compilation of this Synopsis. Errors in the schedules have been detected that otherwise would not have been noticed and less correspondence relating to errors and discrepancies has been necessary. While compilation of data has been facilitated, analysis of data and drawing conclusions on the basis of comparison with previous years has been more difficult and less satisfactory, partly because of a change in the method of determining sucrose in final molasses, but principally on account of the disturbing effect of averaging figures for the Petree process with figures for the usual process. These discrepancies were discussed in the 1923 Synopsis and need not be repeated here. As the same proportion of the crop, 16 per cent, was manufactured in Petree process factories, both in 1924 and 1925, averages for these two seasons except those influenced by molasses purity may be compared directly. Table III, containing averages for the past four years for factories that do not use the Petree process, has been included again. It is becoming impracticable, however, to make at all close comparisons of averages affected by the Petree process, such as extraction, recovery, clarification results and filter press work, with corresponding averages for years prior to 1924 and but few such comparisons have been attempted.

Varieties of Cane

Cane varieties making up 1 per cent or more of the total crop have been classed as major varieties and listed in Table I. Eight varieties, the same number as last year, are included in this classification. Yellow Caledonia and D 1135 are the most widely distributed, each of these varieties making up 1 per cent or more of the crop of thirty-one plantations. H 109, reported from twenty-three

TABLE NO. 2

COMPOSITION OF CANE BY ISLANDS

	Hawaii	Maui	Oahu	Kauai	Whole Group
1916					
Polarization	12.54	14.62	13.74	13.26	13.45
Per cent Fiber..............	13.22	12.22	12.51	12.86	12.74
Purity 1st Expressed Juice...	87.56	89.41	87.15	86.26	87.70
Quality Ratio	.....	.....	.....	.....	8.22
1917					
Polarization	13.31	15.43	13.55	13.13	13.76
Per cent Fiber..............	13.23	11.67	12.25	12.89	12.62
Purity 1st Expressed Juice...	88.11	90.40	86.77	86.70	88.02
Quality Ratio	8.21	7.03	8.20	8.27	7.95
1918					
Polarization	11.88	14.25	13.50	12.54	12.97
Per cent Fiber..............	13.35	11.53	12.23	12.84	12.50
Purity 1st Expressed Juice...	87.27	88.62	86.93	85.88	87.18
Quality Ratio	9.27	7.73	8.27	8.60	8.47
1919					
Polarization	12.74	15.12	14.24	13.52	13.74
Per cent Fiber..............	13.07	11.74	12.14	12.61	12.49
Purity 1st Expressed Juice...	87.54	88.81	87.00	85.82	87.34
Quality Ratio	8.66	7.25	7.81	8.20	8.05
1920					
Polarization	12.86	15.29	13.75	13.07	13.64
Per cent Fiber..............	13.36	11.39	12.65	12.72	12.64
Purity 1st Expressed Juice...	87.87	88.94	85.40	86.52	87.24
Quality Ratio	8.45	7.08	8.07	8.28	8.00
1921					
Polarization	12.25	14.67	13.72	12.67	13.12
Per cent Fiber..............	13.28	11.82	12.40	13.28	12.80
Purity 1st Expressed Juice...	87.18	87.37	85.46	84.07	86.22
Quality Ratio	8.98	7.51	8.11	8.76	8.41
1922					
Polarization	12.07	13.95	13.61	13.03	12.97
Per cent Fiber..............	13.16	12.38	12.88	13.22	12.95
Purity 1st Expressed Juice...	87.17	87.88	86.18	85.80	86.84
Quality Ratio	9.19	7.75	8.04	8.36	8.45
1923					
Polarization	12.09	13.61	12.99	12.94	12.78
Per cent Fiber..............	13.14	12.01	12.86	12.99	12.82
Purity 1st Expressed Juice...	87.61	88.65	85.52	86.58	87.05
Quality Ratio	9.12	7.91	8.50	8.42	8.57
1924					
Polarization	12.44	14.34	13.48	13.34	13.26
Per cent Fiber..............	12.99	12.16	12.72	12.94	12.74
Purity 1st Expressed Juice...	87.98	89.19	87.02	87.31	87.86
Quality Ratio	8.86	7.58	8.16	8.12	8.25
1925					
Polarization	12.35	14.42	13.52	13.24	13.22
Per cent Fiber..............	12.92	12.40	12.60	12.91	12.74
Purity 1st Expressed Juice...	88.02	89.36	87.11	87.19	87.92
Quality Ratio	8.92	7.47	8.18	8.21	8.28

plantations, is third, and Yellow Tip, reported from eighteen plantations, is fourth in distribution. Nine plantations only ground Lahaina this season against twelve in 1924 and fifteen in 1923.

H 109, while third in distribution, is first in tonnage ground, having materially increased its lead. Yellow Tip is now in fifth place, having displaced Striped Mexican. This is the only change in the ranking of the major varieties, though Yellow Tip will probably displace Lahaina from fourth place in another year.

Increased proportions of but two major varieties, H 109 and Yellow Tip, were ground. The proportion of Yellow Caledonia, Lahaina, Striped Mexican and Rose Bamboo decreased materially. The latter will probably be classed among the minor varieties in another season or two.

Varieties making up 1 per cent or more of the crop of any one plantation but less than 1 per cent of the total crop, are classed as minor varieties. These are shown in the following tabulation. Minor varieties listed in the 1924 Synopsis are also given for convenient comparison:

Variety	Per cent of total crop 1924	1925
D 117	.49	.52
Badila	.46	.35
H 146	.51	.26
Yellow Bamboo	.02	.14
Uba	.03	.11
H 456	...	.11
H 20	...	.10
White Bamboo	.11	.06
H 227	...	.05
Total	1.62	1.70

H 456 is in this classification for the first time. This variety made up more than 1 per cent of the crop at two plantations, Makee and McBryde, and was also reported from a third plantation, Kilauea.

Quality of Cane

Table II contains data on quality of cane for the whole group and by islands for the last ten years. This season the cane was slightly poorer than in 1924. Fiber was identical in both seasons. Slightly higher juice purity this year was more than offset by lower polarization, resulting in a quality ratio of 8.28 against 8.25 in 1924.

Changes since last year in the quality of cane on individual islands are small, the largest being an improvement of from 7.58 to 7.47 in quality ratio on Maui. The cane was of poorer quality on Hawaii and Kauai. On Oahu the quality differs but slightly from last year. Oahu figures show an apparent discrepancy. Both juice purity and cane polarization are slightly higher, yet the quality ratio increased from 8.16 to 8.18. The apparent discrepancy is due to an increase of 0.5 in Java ratio, or ratio of cane polarization to first expressed juice polarization.

TABLE NO. 3.

True Averages of All Factories Except Those Now Using the Petree Process.

	1922	1923	1924	1925
Cane—				
Polarization	12.77	12.66	13.08	12.99
Fiber	13.03	12.91	12.82	12.80
Tons per ton sugar	8.76	8.68	8.40	8.45
Bagasse—				
Polarization	1.71	1.53	1.52	1.54
Moisture	41.31	41.29	41.26	41.25
Fiber	56.23	56.48	56.74	56.55
Polarization per cent cane	0.40	0.35	0.34	0.35
Polarization per cent polarization of cane	3.11	2.76	2.63	2.69
Milling loss	3.05	2.71	2.68	2.73
Weight per cent cane	23.16	22.84	22.59	22.63
First Expressed Juice—				
Brix	18.23	17.99	18.34	18.14
Polarization	15.79	15.61	16.07	15.91
Purity	86.58	86.77	87.61	87.67
"Java ratio"	80.9	81.1	81.4	81.7
Mixed Juice—				
Brix	13.26	13.11	13.37	13.44
Polarization	11.07	11.00	11.31	11.38
Purity	83.50	83.87	84.56	84.67
Weight per cent cane	111.65	111.95	112.66	111.03
Polarization per cent cane	12.38	12.31	12.74	12.64
Extraction	96.89	97.24	97.37	97.31
Extraction ratio	0.24	0.21	0.21	0.21
Last Expressed Juice—				
Polarization	1.96	1.73	1.84	1.90
Purity	68.66	68.48	71.73	69.63
Maceration per cent cane	34.99	34.79	35.30	33.66
Syrup—				
Brix	63.11	63.33	63.18	63.63
Purity	84.81	85.40	86.02	85.95
Increase in purity	1.31	1.53	1.46	1.28
Press Cake—				
Polarization	1.96	2.20	2.16	2.17
Weight per cent cane	2.49	2.45	2.45	2.45
Polarization per cent cane	0.05	0.05	0.05	0.05
Polarization per cent polarization of cane	0.38	0.43	0.40	0.41
Lime used per cent cane	0.081	0.085	0.086	0.078
Commercial Sugar—				
Polarization	96.88	96.88	97.20	97.23
Moisture	0.85	0.80	0.73	0.74
Weight per cent cane	11.41	11.53	11.91	11.83
Polarization per cent cane	11.06	11.17	11.58	11.50
Polarization per cent polarization of cane	86.94	88.37	88.76	88.78
Polarization per cent polarization of juice	89.69	90.86	91.16	91.24
Final Molasses—				
Weight per cent cane	3.14	2.96	2.83	2.82
Sucrose per cent cane	1.07	0.99	0.97	0.93
Sucrose per cent polarization of cane	8.33	7.79	7.45	7.20
Sucrose per cent polarization of juice	8.60	8.01	7.65	7.40
Gravity solids	87.94	88.54	89.08	90.09
Gravity purity	38.60	37.68	37.81	36.97
Undetermined Losses—				
Polarization per cent cane	0.21	0.11	0.14	0.16
Polarization per cent polarization of cane	1.28	0.65	0.76	0.92

Quality ratio is calculated from the first expressed juice analysis. The polarization of the latter decreased sufficiently to more than offset the increase in purity and thus give a higher figure for quality ratio.

Juice purities were higher than in the preceding season on Maui, Hawaii and Oahu, but were lower on Kauai. The average first expressed juice purity was the highest in eight years.

For several years fiber in the cane has consistently decreased on Hawaii, where fiber is usually the highest, and has increased on Maui where the fiber is usually lowest. While in former years fiber content on different islands sometimes differed by as much as 1.5 per cent or 2 per cent, the maximum difference this season is but .5 per cent.

Chemical Control and Sucrose Balances

A new method for determining sucrose in final molasses has been used this season. Sucrose determinations by the old method were somewhat too high, due to the influence of the lead precipitate. This error is avoided in the new method, the figure obtained more nearly approximating the true sucrose content. The average gravity purity this year is 37.32 against 38.16 in 1924. The difference is partly due to the change in method. Just how much cannot be stated definitely, particularly as in some instances the old method was used early in the season. On the basis of present information, the writer estimates that approximately a half of the difference is due to lower sucrose figures obtained with the new method.

The juice entering the boiling house is now weighed at all except four factories. Molasses is weighed at twenty-five factories and measured at ten, while at five factories it is neither weighed nor measured. Seven factories have failed to report the amount of molasses produced, rendering the figures for molasses less complete than in any year since 1920.

Twenty-seven factories have reported results on a sucrose basis this year, an increase of two. Gravity solids and sucrose balances for these factories are in Table V. One factory reports a negative undetermined sucrose loss. On a polarization basis, the basis used in compiling the large table, with good factory work a small negative undetermined loss is possible, but on a true sucrose basis negative undetermined losses can be attributed only to errors in control.

Apparent boiling house recoveries and molasses produced on theoretical are in Table VI. True boiling house recoveries are in Table VII. These tables are principally checks on the accuracy of the chemical control, though low figures are equally indicative of losses.

Deficiencies in control methods depressing the calculated figure for available below what it should be were discussed in the 1924 Synopsis. In the last few years, following changes in clarification practice, an increased number of factories have reported recoveries on available exceeding 100 per cent. This is the case this year with almost a half of the factories listed in Table VI and over a third of the factories listed in Table VII. While it is probable that slightly over 100 per cent recovery on the calculated available can be secured with good factory

TABLE NO. 4—MILLING RESULTS.

Showing the Rank of the Factories on the Basis of Milling Loss.

Factory	Milling Loss	Extraction Ratio	Extraction	Equipment
1. Hakalau	1.08	0.09	98.93	2RC54,12RM9-60,3-66
2. Waimanalo	1.12	0.09	98.73	K,3RC54,9RM54
3. Onomea	1.18	0.10	98.73	2RC60,S54,12RM66
4. Hilo	1.43	0.12	98.39	K,2RC60,12RM66
5. Olowalu	1.82	0.14	98.17	K,3RC48,9RM48
6. Kekaha	1.83	0.13	98.36	2RC54,15RM60
7. Honomu	1.94	0.15	98.15	3RC60,9RM60
8. Wailuku	1.95	0.14	98.37	K,2RC72,12RM78
9. Pepeekeo	2.00	0.16	98.10	2RC54,9RM60
10. Paauhau	2.23	0.19	97.57	2RC60,12RM66
11. Ewa	2.28	0.17	97.99	K(2),2RC78,18RM78
12. Lihue	2.40	0.19	97.59	K,2RC78,S72,12RM78
13. Kilauea	2.57	0.22	97.11	K,S,3RC60,9RM60
14. Koloa	2.68	0.22	96.84	K,2RC60,12RM66
15. Kahuku	2.69	0.23	96.71	K,2RC60,S54,9RM72
16. Pioneer	2.77	0.20	97.38	K,2RC72,S72,15RM72
17. McBryde	2.78	0.20	97.21	K,2RC72,S72,9RM84
18. Haw. Sug.	2.83	0.19	97.75	K,2RC72,S72,12RM78
19. Laupahoehoe	2.85	0.22	97.04	K,2RC54,9RM60
20. Waialua	2.93	0.21	97.25	K(2),2RC78,12RM78
21. Honolulu	3.01	0.22	97.35	K(2),S54,2RC78,9RM78
22. Hamakua	3.04	0.23	96.67	K,2RC60,12RM60
23. Oahu	3.07	0.22	97.29	K(2),2RC78(2),S72(2),12RM78(2)
24. Olaa	3.11	0.24	96.90	K,S72,12RM78
25. Waianae	3.11	0.22	96.73	K(2),12RM60
26. Makee	3.16	0.25	96.60	K,2RC72,S72,9RM72
27. Haw. Agr.	3.24	0.26	96.72	3RC60,12RM66
28. Waimea	3.29	0.25	96.89	2RC48,12RM42
29. Kohala	3.35	0.27	96.64	K(2),3RC60,9RM60
30. H. C. & S. Co.	3.37	0.23	97.23	K(4),2RC78(2),S72(2),12RM78(2)
31. Maui Agr.	3.46	0.23	97.22	K(2),3RC66,18RM66
32. Kaiwiki	3.68	0.29	96.05	K,2RC60,9RM60
33. Hawi	3.80	0.30	96.26	K(2),3RC48,12RM3-48,9-54
34. Hutchinson	3.94	0.32	96.42	2RC60,9RM60
35. Waiakea	4.11	0.33	95.31	K,2RC60,9RM60
36. Honokaa	4.16	0.37	95.31	K(2),2RC66,12RM66
37. Kaeleku	4.20	0.35	95.05	K,2RC54,9RM60
38. Union Mill	4.28	0.36	94.91	K,9RM60
39. Halawa	5.15	0.45	93.80	K,2RC60,6RM50
40. Niulii	7.24	0.66	90.29	K,9RM54

work, the writer considers recoveries of over 101 per cent on a true sucrose basis (Table VII) strongly indicative of errors in weights or analyses, or that excessive deductions have been made for suspended solids in mixed juice or for press washings returned to the mill. Three factories listed in Table VII show over 101 per cent recovery on the calculated available.

Figures for molasses produced on the theoretical in Table VI continue to show wide variations, though from year to year the tendency has been toward more consistent figures. As in previous years, the theoretical amount of solids in molasses has been assumed to be gravity solids in the syrup less solids accounted for in commercial sugar. Less than the theoretical amount of molasses, as thus calculated, should be actually produced for reasons discussed in previous Synopses. The average reported for the preceding four seasons was 88.8 per cent, a figure identical with the average for this year. If we assume that a range of five points above and below this average includes all reasonably accurate figures, this tabulation indicates the probability of losses or errors in control at ten factories.

Extra Fuel

As would be expected, with the increase in grinding rate, a reduced amount of extra fuel has been burned. The reduction amounts to between 8 and 9 per cent.

Milling

Bagasse moisture has decreased .02 but bagasse polarization has increased an equal amount, thus increasing the milling loss from 2.78 to 2.82 and decreasing the extraction from 97.33 to 97.29.

Averages for tons of cane ground per hour, tonnage ratio and pressure per foot of roller for the past few seasons are tabulated below:

Year	Tons cane per hour	Tonnage ratio	Tons pressure per linear foot of roller
1920	39.34	....	....
1921	36.58	1.40	....
1922	39.93	1.54	65.2
1923	42.03	1.56	66.2
1924	43.63	1.62	66.9
1925	45.31	1.71	66.5

The increase in grinding rate over 1924 is 1.68 tons of cane per hour, equivalent to 4 per cent. In comparison with 1921 when the grinding rate was the lowest in recent years, the increase is 24 per cent. Operating at higher capacity has been quite general, twenty-eight factories reporting increases against ten reporting decreases. All decreases were small, in but three or four instances exceeding .05 in tonnage ratio and in no case exceeding .1. The increase in grinding rate has been through operating existing equipment at higher capacities, no additional milling equipment having been installed.

TABLE NO. 5
GRAVITY SOLIDS AND SUCROSE BALANCES

Factory	GRAVITY SOLIDS PER 100 GRAVITY SOLIDS IN MIXED JUICE				SUCROSE PER 100 SUCROSE IN MIXED JUICE			
	Press Cake	Commercial Sugar	Final Molasses	Undetermined	Press Cake	Commercial Sugar	Final Molasses	Undetermined
H. C. & S. C.	2.5	84.2	12.0	1.3	0.5	94.4	5.2	—0.1
Oahu	2.9	79.8	14.7	2.6	0.5	92.2	6.5	0.8
Ewa	5.4	76.5	16.7	1.4	0.4	90.9	7.2	1.5
Waialua	3.6	77.2	15.8	3.4	0.5	90.5	7.2	1.8
Pioneer	4.3	77.8	15.8	2.1	0.4	91.3	6.8	1.5
Haw. Sug	5.3	79.7	15.1	—0.1	0.4	93.1	6.4	0.1
Maui Agr.	0	82.1	17.9	0	0	91.4	8.1	0.5
Lihue	3.0	75.5	18.2	3.3	0.3	90.2	7.9	1.6
Onomea	4.9	78.7	15.4	1.0	0.1	92.6	6.7	0.6
Hilo	4.2	77.9	16.0	1.9	0.3	92.3	7.2	0.2
Haw. Agr.	3.4	76.3	15.0	5.3	0.3	87.7	6.7	5.3
Hakalau	3.6	79.0	15.2	2.2	0.1	93.0	6.5	0.4
Wailuku	4.1	78.8	15.7	1.4	0.5	91.8	7.2	0.5
Makee	3.6	74.8	19.2	2.4	0.4	88.9	9.1	1.6
McBryde	4.4	77.7	17.6	0.3	0.2	91.1	7.8	0.9
Honokaa	5.8	75.6	17.2	1.4	0.4	91.1	7.9	0.6
Laupahoehoe	4.1	79.1	13.5	3.3	0.2	91.9	6.3	1.6
Pepeekeo	4.0	78.5	15.0	2.5	0.2	92.9	6.0	0.9
Hamakua	0	81.4	17.1	1.5	0	90.8	8.3	0.9
Kahuku	5.4	74.5	18.5	1.6	0.3	91.8	7.5	0.4
Paauhau	4.6	77.5	16.3	1.6	0.1	91.8	7.2	0.9
Honomu	5.4	77.5	16.2	0.9	0.3	91.8	7.0	0.9
Koloa	5.3	73.7	17.4	3.6	0.7	89.8	7.9	1.6
Hutchinson	4.1	75.6	17.1	3.2	0.6	88.9	8.5	2.0
Waiakea	3.2	76.8	16.4	3.6	0.7	89.6	7.8	1.9
Kilauea	4.2	69.8	21.7	4.3	1.2	86.2	10.2	2.4
Waimanalo	3.9	73.6	19.4	3.1	0.5	89.8	9.0	0.7

Pressure per foot of roller has been reduced 0.4 tons below the 1924 figure, though it was higher than in the previous two years for which averages are available.

Maceration has been reduced from 34.90 to 33.66 per cent. The amount of water added per hour is approximately the same as in 1924. Twenty-four factories report reduced maceration against sixteen reporting increases. From data discussed under "Evaporation," it would seem that evaporator capacity was sufficient to have brought the syrup to a fair density with the same amount of maceration as in 1924. It is quite probable that getting the extra quantity of cane through the mill as well as evaporator capacity has been a factor influencing the reduction in maceration.

It seems of interest to note the trend of changes in maceration practice during the seventeen years in which the figures for maceration have been averaged. Starting with 27.12 per cent in 1909, the amount was increased quite consistently until 40.80 per cent was used in 1919. Since then the tendency has been toward decreased maceration, the 33.63 per cent applied this year being but 82 per cent of the maximum in 1919 and the smallest amount since 1913. This means that maceration has been reduced to the amount applied before Messchaert grooves were introduced. In 1914, with maceration closely approximating the amount used during the past season, extraction was but 95.46.

The reported surface speed of the rollers increased slightly; some 4 per cent for two-roller crushers and 1 per cent for three-roller mills.

Mill settings were slightly wider. Attempting to reduce the change to a percentage basis is not entirely satisfactory, yet after carefully examining available data the writer believes that the following average figures are approximately correct: 15 per cent increase in crusher settings and from 2 to 2.5 per cent increase in mill settings. The proportionate increase in actual openings while grinding would be considerably less than the above figures on account of roller rise, slack, etc.

Comparatively few changes have been made in surface grooving. Coarse grooved rollers have been installed in first mills in one or two instances, but with this exception the changes reported show no definite tendency either toward coarser or finer grooving.

No changes of any consequence have been made in juice grooving.

Examination of data from individual factories indicates reduction in pressure and maceration as the factors principally responsible for the somewhat poorer milling results this year. Wider openings also appear to have adversely influenced extraction in some instances.

A very satisfactory feature of the milling work this year is the smaller difference in purity between first expressed and mixed juice. This has decreased from 2.81 to 2.72. The improvement is also reflected by an increase in Java ratio from 81.55 to 81.64. Lower extraction has tended to reduce the difference in juice purities but the effect of this year's small decrease in extraction is probably negligible. The principal factors affecting it are field trash on the cane and sanitation at the mill. No data definitely indicating the amount of field trash are available. We do know that considerable attention is being given to prevent-

TABLE NO. 6

APPARENT BOILING-HOUSE RECOVERY

Comparing per cent available sucrose in the syrup (calculated by formula) with per cent polarization actually obtained

Factory	Available*	Obtained	Recovery on Available	Molasses Produced on Theoretical
H. C. & S. Co	93.55	95.69	102.3	90.2
Oahu	92.12	92.68†	100.6	85.1
Ewa	92.63	92.25	99.6	93.9
Waialua	91.50	91.71	100.2	83.4
Pioneer	92.37	92.42	100.1	87.8
Olaa	91.88	90.81	98.8	95.7
Haw. Sugar	93.67	93.46†	99.8	100.4
Maui Agr.	91.88	91.45†	99.5	100.2
Lihue	90.69	91.26	100.6	85.8
Onomea	93.21	92.98	99.8	93.8
Hilo	91.64	92.67	101.1	88.4
Kekaha	90.69	90.79	100.1	89.4
Haw. Agr	92.49	88.68	95.9	73.3
Hakalau	92.31	93.18	100.9	87.0
Wailuku	91.91	92.74	100.9	92.3
Makee	89.90	89.93	100.0	89.3
McBryde	92.41	91.90	99.4	98.9
Honokaa	91.30	91.80	100.5	91.6
Laupahoehoe	92.39	91.86	99.4	78.7
Pepeekeo	92.98	93.59	100.7	86.0
Hamakua	91.27	91.15	99.9	92.0
Kahuku	91.41	93.11	101.9	92.1
Paauhau	92.27	92.08	99.8	91.0
Honomu	92.74	92.61	99.9	95.5
Koloa	90.35	91.09	100.8	83.7
Hutchinson	90.62	89.56	98.8	85.9
Waiakea	90.88	90.76	99.9	83.4
Hawi	92.23	86.91	94.2	....
Kaiwiki	91.61	91.57	100.0	88.8
Waianae	88.24	85.22	96.6	....
Kohala	92.40	92.04	99.6	92.9
Kilauea	88.27	87.83	99.5	86.3
Kaeleku	90.06	91.47	101.6	82.0
Waimanalo	89.37	90.74	101.5	88.2
Union Mill	90.36	90.11	99.7	....
Halawa	90.04	90.26	100.2	....
Waimea	91.60	90.11	98.4	....
Olowalu	88.77	84.55	95.2	78.2
Niulii	88.15	86.47	98.1	....

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When the moisture in the sugar has not been reported 1 per cent has been taken. 38 has been used when the gravity purity of the molasses has not been reported.

† Sucrose.

ing sour accumulations around mills, juice strainers, etc., and judging from observations during factory inspections, sanitary conditions around milling plants are better than in former years. To the extent that improvement in mixed juice purity is due either to reduced amounts of trash or better mill sanitation, it reflects a saving of sugar that otherwise would be lost. Starting with a first expressed juice purity .06 higher than in 1924, the reduction of .09 in the decrease from first expressed to mixed juice purity has resulted in a mixed juice purity .15 higher than last year.

Factories are listed in the order of the size of the milling loss in Table IV. This table shows fewer large changes in relative standing than in recent years. Factories with improved standing amounting to five points or more are Kilauea (19 to 13), Koloa (22 to 14), Laupahoehoe (29 to 19), and Waialua (30 to 20). Factories that have dropped five points or more in relative standing are Pioneer (11 to 16), Hamakua (12 to 22), Makee (15 to 26), Haw. Agr. (20 to 27), Hutchinson (24 to 34), and Honokaa (27 to 36).

The first ten factories in Table IV last year are again the first ten this year with but little change in relative order except that Olowalu has advanced from ninth to fifth place. 98 extraction or better was secured at nine factories, equalling the maximum number in any previous year. Milling loss was reduced to less than 2.0 at eight factories; seven was the maximum number in any previous year. Hakalau has made a new record in milling loss reporting 1.08 for the season. Hakalau and Onomea shared the previous record in milling loss, both reporting 1.09 in 1923.

Boiling House Work

Clarification: Results in clarification have been decidedly unsatisfactory, a .20 smaller increase in purity from mixed juice to syrup offsetting the benefits that should have been realized from higher initial purities and reducing the syrup purity to .05 lower than last year. Had the increase in purity been as large as last year the syrup purity would have been 86.47, which is higher than in any year since 1915. Such a result should have improved recovery by some .15, and additional benefits should have been secured through reduced inversion losses.

The average for increase in purity in the large table, at its face value, is the lowest on record. While directly comparable with the corresponding figure for the previous season, it is not directly comparable with figures for seasons prior to 1924 because of discrepancies in the averages caused by including figures for the Petree process. So far as can be inferred from available data, the actual increase in purity this year was better than in 1921 but poorer than any other year for which we have a record.

The average for increase in purity in Table III for factories that do not use the Petree process is smaller than in the other three years for which separate averages from these factories are available.

A close estimate of increases in purity in Petree process clarification cannot be made for mixed juice figures are not available and comparisons with the first expressed juice purity, the only value that can be used as a basis for comparison,

TABLE NO. 7

TRUE BOILING-HOUSE RECOVERY

Comparing per cent sucrose available and recovered

Factory	Available	Obtained*	% Recovery on Available
H. C. & S. Co.	93.79	94.87	101.2
Oahu	92.12	92.66	100.6
Ewa	92.65	91.27	98.5
Waialua	91.35	90.96	99.6
Pioneer	92.54	91.67	99.1
Haw. Sug.	93.67	93.47	99.8
Maui Agr.	91.88	91.44	99.5
Lihue	90.79	90.47	99.6
Onomea	92.97	92.69	99.7
Hilo	91.43	92.58	101.3
Haw. Agr.	92.77	87.96	94.8
Hakalau	92.23	93.09	100.9
Wailuku	91.96	92.26	100.3
Makee	90.00	89.26	99.2
McBryde	92.57	91.28	98.6
Honokaa	91.26	91.47	100.2
Laupahoehoe	92.16	92.08	99.9
Pepeekeo	93.02	93.09	100.1
Hamakua	91.13	90.78	99.6
Kahuku	91.65	92.08	100.5
Paauhau	92.15	91.89	99.7
Honomu	92.81	92.08	99.2
Koloa	90.31	90.43	100.1
Hutchinson	90.23	89.44	99.1
Waiakea	90.59	90.23	99.6
Kilauea	87.87	87.25	99.3
Waimanalo	89.16	90.25	101.2

are complicated because this comparison indicates the combined effect of milling and clarification. So far as can be determined from available data, average clarification results at Petree process factories have been less satisfactory than in the previous year in about the same proportion as at factories using filter presses.

The reason for poorer results in clarification is reflected in figures for the amount of lime used. This has been reduced from .086 to .079 per cent on cane. At the increased grinding rate it has, no doubt, been necessary to reduce the volume of settlings, whether they are returned to the mill or filtered. The volume of settlings can be reduced by reducing the amount of lime, but with the average quantity of lime now used, such reduction can be made only at the expense of smaller increases in purity and increased losses through inversion.

The following figures bring out an interesting relation between lime used and impurities removed. The figures for impurities removed are calculated from apparent purities and are not absolute, but they are quite closely, though not exactly, comparable:

	1924	1925	Per cent reduction in 1925
Lime used per cent impurities in mixed juice..........	3.71	3.41	8.09
Per cent of total impurities removed..................	11.0	9.64	12.36

On the whole, data in these Synopses for the past five or six years, strongly confirm the results of research on clarification at the Experiment Station and emphasize the need of developing filtration equipment better suited to the duties imposed on it.

The following figures for purity difference between first expressed juice and syrup show the combined effect of conditions at the mill and clarification during the last few years:

Year	Purity difference first expressed juice to syrup
1921	2.32
1922	1.88
1923	1.40
1924	1.54
1925	1.65

These figures show a decidedly unfavorable trend in the last two years.

Filter Presses: The following is based on data for factories which do not use the Petree process, in Table III. In the past three seasons the same percentage of press cake on cane has been reported and differences in the polarization of the press cake have been small. Both the polarization of the press cake and the loss in press cake per cent polarization in cane have increased .01 over last year.

Evaporation: The syrup was evaporated to 63.65 Brix. This is .33 higher than last year and is higher than in any previous year. 2.6 per cent more water was evaporated per hour than in 1924 and some 18 per cent more than in 1921. At this rate of evaporation, if the same amount of maceration had been applied

TABLE NO. 8

COMPARISON OF ACTUAL AND CALCULATED RECOVERIES

The factories are arranged in the order of the ratio of their recovery to that resulting from 100% extraction, reducing the molasses to 37.5 gravity purity, and eliminating all other losses. Factories reporting a recovery of over 101% of the available (Table No. 6) are omitted from this tabulation.

No.	Factory	Milling	Boiling House	Over All
1	Hakalau.............	98.93	101.48	100.55
2	Pepeekeo............	98.10	102.17	100.39
3	Lihue..............	97.59	101.21	99.13
4	Onomea.............	98.73	100.06	99.00
5	Honomu.............	98.15	100.09	98.51
6	Wailuku.............	98.37	99.85	98.46
7	Ewa................	97.99	99.89	98.21
8	Pioneer.............	97.38	100.09	97.93
9	Haw. Sug............	97.75	99.95	97.93
10	Paauhau............	97.57	99.97	97.87
11	Koloa...............	96.84	100.40	97.82
12	Oahu................	97.29	100.14	97.80
13	Kekaha............	98.36	98.58	97.14
14	Waialua.............	97.25	99.45	97.05
15	McBryde............	97.21	99.45	96.92
16	Maui Agr...........	97.22	98.74	96.47
17	Kilauea.............	97.11	98.26	95.88
18	Makee..............	96.60	98.81	95.84
19	Honokaa............	95.31	100.09	95.82
20	Laupahoehoe........	97.04	98.51	95.80
21	Hamakua............	96.67	98.08	95.33
22	Kohala..............	96.64	98.26	95.31
23	Olaa................	96.90	97.89	95.27
24	Waimea............	96.89	97.70	95.06
25	Kaiwiki.............	96.05	98.53	94.96
26	Waiakea............	95.31	98.19	93.99
27	Hutchinson.........	96.42	96.67	93.61
28	Haw. Agr...........	96.72	95.34	92.49
29	Union Mill..........	94.91	96.84	92.29
30	Olowalu............	98.17	93.64	92.24
31	Halawa.............	93.80	97.59	91.92
32	Waianae...........	96.73	94.37	91.72
33	Hawi...............	96.26	93.13	90.08
34	Niulii...............	90.29	95.22	86.57

as in 1924, the syrup would have been evaporated to 60.4 Brix. At the lower density, however, under otherwise equal conditions, the amount of water evaporated per hour would be slightly higher, indicating that with the same amount of maceration as last year, an average density of between 60.5 and 61.0 could have been attained. Under these circumstances, it does not seem that the reduction in maceration can be attributed entirely to lack of evaporator capacity.

Commercial Sugar: The polarization of the commercial sugar has been increased from 97.18 to 97.22. The change is in the right direction. The moisture content of the sugar has not been reduced in proportion to the increase in polarization; in fact, moisture figures carried to the third decimal place indicate a slight increase rather than a decrease. The deterioration factor has increased from .265 to .269. Such deterioration factors are not safe and more or less deterioration may be expected when sugar is not more thoroughly dried. The grain of the sugar has been considerably smaller in the past season. This has been a factor tending toward less satisfactory drying.

The increase in sugar polarization, under otherwise equal conditions, reduces sucrose recovery to the extent of .02. This is due to less molasses in the higher polarizing sugar. It does not indicate a reduction in recovery of available sugar.

Low Grades: Though lower syrup purity and increased grinding rate have increased the duty on low grade equipment approximately 4 per cent, the quality of the low grade work has materially improved. The gravity purity of the final molasses has been reduced to 37.32, the lowest average on record. As previously noted, a part of this decrease is due to a change in analytical methods, but after making full allowance for the probable effect of this change, this year's average is lower than that of any previous season. Figures for molasses density disclose the reason for the improvement, this year's average being 89.75 Brix, a figure .94 higher than the previous high mark last year.

Due to low purity and high density, the weight of molasses per cent cane and sucrose in molasses per cent cane are lower than in any previous year. Averages for sucrose in molasses per cent polarization of cane and per cent polarization of juice are lower than figures for any previous year except 1915. It is probable that lower averages in that year are because of incomplete molasses data rather than because these losses were actually lower, for at that time a large proportion of the factories did not report molasses weights and at most of these factories molasses purities were high.

In comparison with last year, better low grade work corresponds to an improvement in recovery of .15 or more, according to how much of the decrease in purity is actually attributable to improved work and how much to changes in analytical methods.

For the third successive season, Kahuku has established a new record in final molasses purity, reporting 32.46. Pepeekeo reported 32.96 purity, a figure lower than the previous record and 1.13 lower than the previous low average at this factory.

Recoveries

Factors that have tended toward higher recoveries are higher initial purities, smaller decreases in purity from first expressed to mixed juice and lower molasses purities. Factors that have tended toward lower recoveries are lower extraction, less satisfactory work in clarification, larger losses in press cake, higher sugar polarization and larger undetermined losses. With the exception of clarification, these factors tending toward lower recoveries are small and have been more than offset by the factors tending toward higher recoveries. Both boiling house and total recoveries are higher than last year. Boiling house recovery increased .2. The present figure, 91.59, is the highest since 1909. A new record has been made in total recovery, the present figure, 89.11, being .17 higher than the previous record made last year.

The slightly poorer quality of the cane has caused a decrease in recovery per cent cane from 11.77 to 11.76. Actually, the decrease would have been .02 if the work had been of the same quality as in the previous season. The decrease of but .01 in recovery per cent cane indicates more efficient factory work this year.

Quality ratio figures give a similar indication of more efficient work. The 1924 figures are 8.25 quality ratio, with 8.26 tons of cane required to make a ton of sugar. The 1925 figures are 8.28 quality ratio with 8.27 tons of cane required. The 1924 cane requirement was then .01 ton more than indicated by quality ratio figures, while this year the cane requirement was .01 ton less than the quality ratio, a net gain of .02 ton.

While the results as a whole are better than in 1924, the quality of the work is still below the 1923 standard.

Table VIII, in which factories are ranked in the order of the ratio of actual recovery to a theoretical recovery calculated as indicated in the note accompanying the table, has been included again. A word of caution against drawing too close distinctions on the basis of these figures again seems desirable. As this table is now calculated, differences of 2 per cent or more in the figures in the third column are probably of definite significance but closer distinctions seem hardly justified. After a number of years study of these and other comparisons of a similar nature, the writer has come to the conclusion that no method has yet been devised for accurately expressing operating efficiency in a raw cane sugar factory as a simple percentage figure.

A summary of losses has been compiled in Table IX.

Mr. A. Brodie has made the calculations and compiled the tables in this Synopsis, with some assistance from others in this department.

TABLE NO. 9
SUMMARY OF LOSSES

FACTORY	POUNDS POLARIZATION PER TON OF CANE						POLARIZATION PER 100 CANE						POLARIZATION PER 100 POLARIZATION OF CANE						Syrup Purity	FACTORY
	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL		
H. C. & S. Co.	8.2	1.4	15.2	...	—3.0	21.8*	0.41	0.07	0.76	...	—0.15	1.09*	2.77	0.47	5.15	...	—0.98	7.41*	88.23	H. C. & S. Co.
Oahu	7.6	1.4	17.6	...	2.2	28.8†	0.38	0.07	0.88	...	0.11	1.44†	2.71	0.48	6.31	...	0.77	10.27†	87.10	Oahu
Ewa	5.4	1.2	18.8	...	1.0	26.4	0.27	0.06	0.94	...	0.05	1.32	2.01	0.42	7.14	...	0.42	9.99	85.97	Ewa
Waialua	7.6	1.4	19.4	...	2.8	31.2	0.38	0.07	0.97	...	0.14	1.56	2.75	0.52	7.04	...	0.98	11.29	85.9	Waialua
Pioneer	7.2	1.0	18.6	...	1.8	28.6	0.36	0.05	0.93	...	0.09	1.43	2.62	0.34	6.74	...	0.62	10.32	86.37	Pioneer
Olaa	8.0	1.6	20.6	...	2.0	32.2	0.40	0.08	1.03	...	0.10	1.61	3.10	0.64	8.04	...	0.81	12.59	86.6	Olaa
Haw. Sug.	6.8	1.0	19.0	...	0.4	27.2†	0.34	0.05	0.95	...	0.02	1.36†	2.25	0.35	6.26	...	0.11	8.97†	88.56	Haw. Sug. Co.
Maui Agr.	8.4	...	23.6	...	1.4	33.4†	0.42	...	1.18	...	0.07	1.67†	2.78	...	7.85	...	0.47	11.10†	87.88	Maui Agr.
Lihue	6.0	0.8	19.4	...	1.8	28.0	0.30	0.04	0.97	...	0.09	1.40	2.41	0.29	7.75	...	0.76	11.21	83.65	Lihue
Onomea	3.0	0.2	16.2	...	0.8	20.2	0.15	0.01	0.81	...	0.04	1.01	1.27	0.13	6.61	...	0.30	8.31	87.30	Onomea
Hilo	4.0	0.6	17.4	...	0.0	22.0*	0.20	0.03	0.87	...	0.00	1.10*	1.61	0.27	7.17	...	0.03	9.08*	86.00	Hilo
Kekaha	4.4	1.0	22.8	...	2.0	30.2	0.22	0.05	1.14	...	0.10	1.51	1.64	0.34	8.29	...	0.73	11.00	85.7	Kekaha
Honolulu	7.4	0.4	...	1.0	....	...	0.37	0.02	....	0.05	.....	...	2.65	0.18	....	0.34	...	...	86.37	Honolulu
Haw. Agr.	8.2	0.8	16.4	...	11.0	36.4	0.41	0.04	0.82	...	0.55	1.82	3.28	0.32	6.56	...	4.36	14.52	86.97	Haw. Agr. Co.
Hakalau	2.6	0.4	16.4	...	0.6	20.0	0.13	0.02	0.82	...	0.03	1.00	1.07	0.12	6.48	...	0.26	7.93	85.5	Hakalau
Wailuku	4.6	1.6	20.2	...	—0.2	26.2	0.23	0.08	1.01	...	—0.01	1.31	1.63	0.54	7.17	...	—0.07	9.27	86.7	Wailuku
Makee	8.4	1.0	22.2	...	1.8	33.4	0.42	0.05	1.11	...	0.09	1.67	3.40	0.36	8.95	...	0.75	13.46	84.68	Makee
McBryde	7.6	0.4	20.8	...	0.6	29.4	0.38	0.02	1.04	...	0.03	1.47	2.79	0.19	7.65	...	0.20	10.83	86.32	McBryde
Honokaa	10.6	0.8	17.2	...	0.4	29.0	0.53	0.04	0.86	...	0.02	1.45	4.69	0.38	7.65	...	0.14	12.86	85.09	Honokaa
Laupahoehoe	7.6	0.4	15.8	...	4.4	28.2	0.38	0.02	0.79	...	0.22	1.41	2.96	0.17	6.18	...	1.71	11.02	87.47	Laupahoehoe
Pepeekeo	4.6	0.4	14.4	...	1.0	20.4	0.23	0.02	0.72	...	0.05	1.02	1.90	0.20	5.88	...	0.39	8.37	85.4	Pepeekeo
Hamakua	8.6	...	20.8	...	1.2	30.6	0.43	...	1.04	...	0.06	1.53	3.33	...	8.06	...	0.49	11.88	87.29	Hamakua
Kahuku	7.8	0.8	17.6	...	—1.6	24.6*	0.39	0.04	0.88	...	—0.09	1.22*	3.29	0.32	7.38	...	—0.74	10.25*	83.11	Kahuku
Paauhau	5.8	0.2	16.8	...	1.4	24.2	0.29	0.01	0.84	...	0.07	1.21	2.43	0.13	7.10	...	0.62	10.28	85.75	Paauhau
Honomu	4.6	0.6	17.6	...	0.6	23.4	0.23	0.03	0.88	...	0.03	1.17	1.85	0.24	6.98	...	0.25	9.32	86.7	Honomu
Koloa	7.8	1.8	19.2	...	2.0	30.8	0.39	0.09	0.96	...	0.10	1.54	3.16	0.70	7.78	...	0.78	12.42	83.8	Koloa
Hutchinson	8.8	1.4	20.2	...	4.4	34.8	0.44	0.07	1.01	...	0.22	1.74	3.58	0.55	8.24	...	1.77	14.14	86.33	Hutchinson
Waiakea	11.8	1.6	18.8	...	3.2	35.4	0.59	0.08	0.94	...	0.16	1.77	4.69	0.65	7.49	...	1.26	14.09	85.83	Waiakea
Hawi	9.4	1.2	...	...	31.8	42.4	0.47	0.06	...	...	1.59	2.12	3.74	0.49	....	...	12.54	16.77	86.9	Hawi
Kaiwiki	10.0	1.4	18.8	...	1.6	31.8	0.50	0.07	0.94	...	0.08	1.59	3.95	0.58	7.40	...	0.65	12.58	86.47	Kaiwiki
Waianae	9.2	1.6	...	...	39.8	50.6	0.46	0.08	....	...	1.99	2.53	3.27	0.57	....	...	14.21	18.05	83.14	Waianae
Kohala	8.4	2.4	17.8	...	1.4	30.00	0.42	0.12	0.89	...	0.07	1.50	3.36	0.98	7.05	...	0.56	11.95	86.97	Kohala
Kilauea	6.8	2.8	23.6	...	3.8	37.0	0.34	0.14	1.18	...	0.19	1.85	2.89	1.18	10.03	...	1.65	15.75	81.8	Kilauea
Kaeleku	12.0	1.8	18.2	...	1.2	32.2*	0.60	0.09	0.91	...	0.06	1.66*	4.95	0.73	7.50	...	0.54	13.74*	84.79	Kaeleku
Waimanalo	3.2	1.4	22.4	...	0.4	27.4*	0.16	0.07	1.12	...	0.02	1.37*	1.27	0.54	8.93	...	0.15	10.89*	82.21	Waimanalo
Union Mill	[illegible]	2.6	...	...	22.2	37.0	0.61	0.13	...	...	1.11	1.85	5.09	1.06	....	...	9.28	15.43	85.8	Union Mill
Halawa	[illegible]	3.4	...	...	20.8	38.6	0.72	0.17	...	...	1.04	1.93	6.20	1.45	....	...	8.99	16.64	84.85	Halawa
Waimea	[illegible]	1.2	...	...	25.2	34.6	0.41	0.06	...	...	1.26	1.73	3.11	0.46	....	...	9.54	13.11	85.59	Waimea
Olowalu	[illegible]	1.4	25.8	...	13.0	45.0	0.24	0.07	1.29	...	0.65	2.25	1.83	0.53	10.04	...	5.04	17.44	83.1	Olowalu
Niulii	21.2	1.6	...	...	26.4	49.2	1.06	0.08	...	...	1.32	2.46	9.71	0.70	....	...	12.12	22.53	83.53	Niulii

* A comparison of the available sucrose in the juice with the amount recovered in the boiling-house indicates that there is probably an error in some of the results reported from this factory.

† Sucrose.

Sugar Prices

96° Centrifugals for the Period September 18, 1925, to December 15, 1925

Date	Per Pound	Per Ton	Remarks
Sept. 18, 1925	4.18¢	$83.60	Philippines.
" 21	4.165	83.30	Porto Ricos, 4.18; Cubas, 4.15.
" 22	4.12	82.40	Spot Cubas.
" 23	4.135	82.70	St. Croix, 4.12; Cubas, 4.15.
" 24	4.12	82.40	Spot Cubas.
" 25	4.08	81.60	Cubas.
" 28	4.02	80.40	Cubas.
Oct. 1	3.93	78.60	Cubas.
" 2	3.90	78.00	Philippines.
" 5	3.93	78.60	Philippines.
" 6	3.96	79.20	Philippines.
" 8	3.95	79.00	Porto Ricos, 3.96; Philippines, 3.94.
" 13	3.90	78.00	Philippines.
" 15	3.86	77.20	Cubas.
" 16	3.83	76.60	Cubas.
" 19	3.80	76.00	Cubas, 3.83, 3.77.
" 20	3.77	75.40	Cubas.
" 23	3.74	74.80	Philippines.
" 26	3.725	74.50	Cubas, 3.74, 3.71.
" 27	3.71	74.20	Cubas.
" 28	3.68	73.60	Cubas.
" 30	3.77	75.40	Cubas.
Nov. 4	3.90	78.00	Cubas.
" 7	4.02	80.40	Cubas.
" 12	4.115	82.30	Philippines, 4.08; Cubas, 4.15.
" 13	4.1583	83.16	Cubas, 4.14; Philippines, 4.125; Cubas, 4.21.
" 16	4.18	83.60	Cubas.
" 17	4.05	81.00	Cubas, 4.02, 4.08.
" 25	4.15	83.00	Cubas.
" 30	4.24	84.80	Cubas, 4.21, 4.27.
Dec. 2	4.15	83.00	Cubas.
" 4	4.115	82.30	Cubas, 4.15, 4.08.
" 5	4.15	83.00	Cubas.
" 7	4.08	81.60	Cubas.
" 10	4.02	80.40	Cubas.
" 15	4.14	82.80	Cubas.

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THE HAWAIIAN PLANTERS' RECORD

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Nematodes in Connection With Sugar Cane Root Rot in the Hawaiian Islands

By Frederick Muir and Gertrude Henderson, M. B., Ch. B.

Previous Work in Hawaiian Islands

What part nematodes play in the root trouble of our sugar cane has been under consideration by our Experiment Station for a number of years. In 1906, Dr. N. A. Cobb[1] commenced work on this problem; he described twenty-three species of nematodes found living in the soil around the roots of sugar cane and pointed out the probability of their playing a part in the death and decay of sugar cane roots. These were the first free living Hawaiian nematodes to be studied and described. In 1909, Dr. Cobb[2] reported two nematodes found living within the roots of sugar cane, *Heterodera radicicola* and *Tylenchus similis* Cobb[3], and commented upon the damage done by them. In 1910, L. D. Larsen[4] reported *Heterodera radicicola* in pineapple roots and remarked upon the damage and remedial measures. In 1911, Dr. H. L. Lyon[5] pointed out the increase of *Heterodera radicicola* when certain varieties of beans were used for green manuring. Since then a number of references to this subject have been made in the *Planters' Record* and the Monthly Letter of this Station.

A year ago a combined study of the root rot problem, or problems, was undertaken by the chemical, agricultural, pathological and entomological departments of the Experiment Station and is still being carried on. The following

[1] H. S. P. A. Experiment Station Bull. 5, Pathological Series, 1906, pp. 163-195.
[2] H. S. P. A. Experiment Station Bull. 6, Pathological Series, 1909, pp. 51-74.
[3] This was described as *Tylenchus biformis* Cobb, but was subsequently found to be the same as *Tylenchus similis*.
[4] H. S. P. A. Experiment Station Bull. 10, Pathological Series, 1910, pp. 62-68.
[5] *The Hawaiian Planters' Record*, V, October, 1911, pp. 200-202.

notes on some aspects of the nematode portion of this study are intended for the information of field men on plantations who are interested in the subject.

General Remarks

Nematodes—commonly referred to as thread worms, round worms, wire worms, etc.—constitute one of the largest groups of animals in existence and comparable only to the insects in the number of species. They are the most ubiquitous of all animals for they are found living everywhere except in the air, and even there they are found blown about by the wind in a dehydrated or encysted condition. As free living animals they are found from the Arctic to the Antarctic, and from the tops of mountains to great depths in the oceans; they live equally well in fresh and in salt water. As parasites they are found living in every group of vertebrates and in many invertebrates, while others are parasites in plants. Over twenty species are known to be parasitic in man and of these the most dangerous are Filaria, hook worm and Guinea worm. All our domestic animals are subject to attacks from these parasites and a great many of our plants suffer from a similar infestation, resulting in losses which are enormous in the final count.

In spite of the great importance of the role played by these little creatures in man's economy their study has been sadly neglected, only a few species affecting man or some of his domestic animals being fairly well investigated. This neglect not only relates to the lives and habits of these creatures but is also reflected in the condition of the classification or arrangement of them into orders, families, genera and species, a work that necessarily precedes extensive study of the various species.

The chief causes of this neglect are the minute size of most of the species, obscure habitats, the difficulty of catching, preserving and preparing the specimens for examination and the absence of a good modern textbook. This last should be remedied as soon as possible, as a good, well illustrated work, along with a full, up-to-date catalogue would cause our knowledge to be increased a hundredfold in a few years. Nevertheless, such a work must give equal importance to both the free living and parasitic forms, and not treat the former, which constitute the majority, as of little or no importance.

Appearance and Structure

To the average observer, the term "thread worm" roughly describes the external appearance of these animals. Mostly minute, long, cylindroid organisms, with little or no signs of appendages, whitish or translucent, the head bluntly rounded and the tail either short and bluntly rounded or longer and more drawn out. They differ from earth worms in having no segmentation and so they cannot progress by an alternate longitudinal contraction and elongation, but move forward by a sinuous snake-like movement from side to side. Some species lash themselves from side to side most vigorously, even when attached to a solid surface by the gland at the end of their tails. They can move equally well through the tissues of their hosts, through water or in the soil. In size they

vary from less than one twenty-fifth of an inch to fourteen inches, the free living forms being small, while the giant forms are all parasitic.

While to the casual observer nematodes appear structureless, and are too often illustrated as such in textbooks and medical works, when properly prepared and seen under a high power microscope they are seen to have a complex structure. The mouth is situated at the anterior extremity and is generally closed by two or more lips which may be plain or bear small papillae or setae. The mouth leads either directly into a muscular oesophagus or into a pharyngeal cavity which may be either plain or armed with teeth or other hard structures, the nature and arrangement of which are of importance in classification and, to a large extent, indicate the nature of the food. The intestine is continuous with the oesophagus and is straight, reaching almost to the tail where it joins the anal opening. The excretory system consists of two canals, one on each side, embedded in the lateral thickenings of the subcuticular tissues, joining together and opening on the ventral surface in the anterior end. A "poison gland" also opens at the same place in many forms. In many species a large salivary gland opens into the lumen of the oesophagus a little way behind the junction of pharynx and oesophagus.

On each side of the body, on the lip or head or slightly behind the head, there is an organ called the amphid or lateral organ which leads into the amphidial pouch. These latter run back on each side for some considerable distance and their walls are connected with nerves. These organs have been found on a great number of species and it is probable that they are universal or nearly so. The prevalence of the organs together with their complexity indicate that they are of some importance in the economy of the animal and good reasons have been given for considering them as sense organs by which they are guided to their food and to the opposite sex. It is probable that they respond to chemical stimuli and thus act as our sense of smell and taste. The fact that nematode parasites in animals can find their way to certain tissues, and others in the soil can soon find suitable roots, shows that they must have very efficient sense organs to direct them, and the fact that the sexes can find one another also indicates that they must have directive sense organs of an efficient nature.

The sexes are separate. The female opening is on the ventral side at some point between the opening of the excretory duct and the anus, the position varying in different species; there may be either one or two ovarian tubes and these are comparatively large. The male genital opening is at the anal opening and the sex is generally recognizable by a paired or a single organ, the spicula. The mode of reproduction varies; generally eggs are produced, but in some cases living young; some species first produce spermatazoa, later produce eggs, and she, or he, then fertilizes her own eggs. The number of eggs produced also varies in different species and in some cases is exceedingly great, Van Beneden having computed that as many as 60,000,000 were present in one nematode.

Nematodes Parasitic Upon Plants

We have previously remarked that the nature of the armature of the pharynx indicates the nature of the food. This is distinctly so when we consider those

nematodes which feed upon the juices of living plant tissues. So far as our present knowledge extends all such nematodes are armed with a hollow needle or style, similar to the hollow needle of a hypodermic syringe; the apex is always oblique, as in a hypodermic syringe needle to give it an acute apex and so enable it readily to penetrate the plant tissues. This style arises from the bottom of the pharynx and the hollow through its length forms the only opening into and is continuous with the lumen of the oesophagus. The base of the style is either plain or produced into a trilobed bulb; muscles are attached to the base and proceed to the walls of the body, enabling the style to be thrust forward. The with-

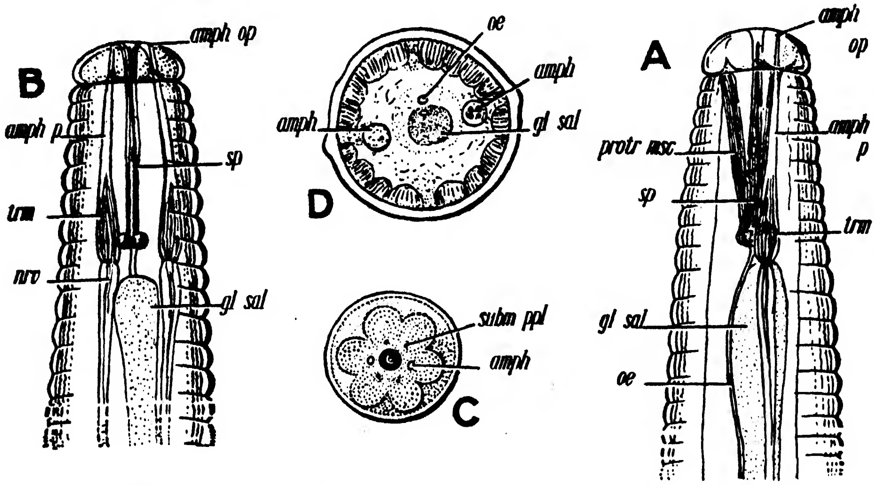


Fig. 1. *Tylenchus dipsaci.* A. Ventro-submedial view of head end. B. Ventral view of head end. C. Front view of head. D. Cross section through the region behind the spear. *Amph op*, amphidial opening; *amph p*, amphidial pouch; *nvr*, apparently amphidial nerve fibres; *oe*, oesophagus; *protr msc*, protractor muscle of the spear; *sal gl*, salivary gland; *sp*, spear; *trm*, terminals. (From Steiner.)

drawal is most likely effected by the contraction of the muscular oesophagus or the muscles of the pharynx. If the lips are fastened to the plant tissue by suction such an arrangement of the muscles would allow of considerable pressure being exerted upon the style.

This piercing organ is always referred to as a "spear" but the term is inadequate as it does not indicate its hollow nature; a term indicating this, such as syphanostyle, is desirable.

The fact that all nematodes truly parasitic upon the living tissues of plants are armed with such a hollow style simplifies our problem, as we can exclude from our main study all those that do not possess one. All nematodes having such a hollow style found in soil around living plant roots, or on leaves or stems, must be under suspicion and experimented with under controlled conditions.

Remarks on Some Local Species

Cobb reported eleven nematodes bearing hollow styles, two of which penetrate into the roots. This does not exhaust the list, as some not reported by him have since been discovered and many more await the investigator. Four of the

species most often found associated with cane roots are mentioned below, others will be reported upon as our knowledge increases.

The Root Gall Nematode, *Heterodera radicicola* (Greeff)

This nematode is now found in nearly all tropical and the warmer parts of temperate climates. Its original habitat is now difficult to determine as it has been carried about by commerce to such a large extent. The wide distribution of this nematode, the large number of plants, both cultivated and wild, which it is reported to attack, the harmful effects it has upon many of its hosts and the lack of any effective measures to control it on a large scale, has made this species the most notorious of the nematodes that attack plants. During the last thirty years much has been written about it but still there are points in its life which we do not fully understand.

The young female in the soil is almost colorless, threadlike, and measures one-fiftieth of an inch or less. Compared with many free living nematodes it is

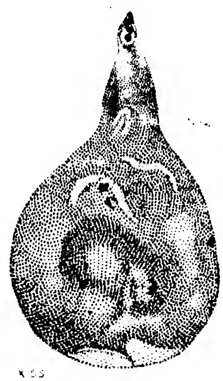


Fig. 2. Large gravid female of *Heterodera radicicola*. (From Cobb.)

not very active but it can soon effectively reach roots suitable for its future home. It is probable that chemical activity at the growing points of the roots is the chief attraction and nerves situated in the walls of the amphidial pouches are the means of perception of the stimulus. The rapidity with which young plants are attacked and the strong sense of host selection which the parasite shows indicate that its sense organs must be efficient. Having found a suitable host root it penetrates as a rule at or near the tip. In sugar cane growing in badly infected areas we have found the first half inch of every young tip to contain from two to twenty young nematodes. The hollow style with its sharp apex is a suitable instrument to penetrate into the root, but once in the young nematode appears to work its way between the cells, especially when moving in the direction of the axis of the root. Having arrived at a suitable position in the young cane root, either in the cortex or the stele, it settles down for life; its food, consisting of the contents of the plant cells, is sucked through the hollow style; the muscular oesophagus, more especially the bulb, serving as a pump to propel the cell con-

tents into the intestine. At first it grows longer, but later it grows fatter till at last it is a small, round, shining, opaquely white body about the size of an ordinary pin's head, with a small protuberance at the head end. The effect of the presence of the nematode upon the plant tissues is interesting; the cells around the head enlarge and contain several nuclei, their increase causing the root at that point to swell up into the conspicuous gall which has given the nematode its popular name. The eggs, varying in number from about forty to some four hundred, remain in the mother nematode where they develop. If the host tissues

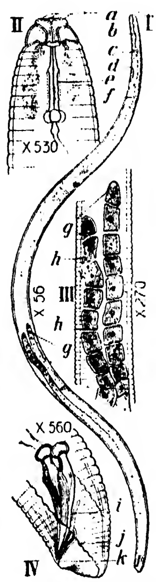


Fig. 3. Male of *Heterodera radicicola.* I, worm in profile. II, head of same more highly magnified. III, middle region of the worm to show the blind ends of the two sexual organs. IV, posterior end. *a*, lips; *b*, oesophageal tube; *c*, median bulb; *d*, excretory pore; *e*, spear; *f*, intestine; *g*. blind end of testicles; *h*, testicles; *i*, spicula; *j*, rudimentary bursa; *k*, anus. (From Cobb.)

be suitable the young break forth from the skin of the dead mother and remain in that locality, but if the host tissues be not suitable then the young set forth in search of a new root. While in the mother skin the eggs or young appear to be able to undergo a great deal of desiccation and remain dormant for a considerable period. The cause of the formation of the gall is obscure; the simple mechanical irritation due to the presence of the nematode does not appear to be the stimulus which causes the plant cells to develop so abnormally, as other nematodes (i. e., *Heterodera schachtii, Tylenchus similis*) live in the root tissues and do not cause a gall. It is therefore possibly due to a secretion, probably derived from the salivary gland.

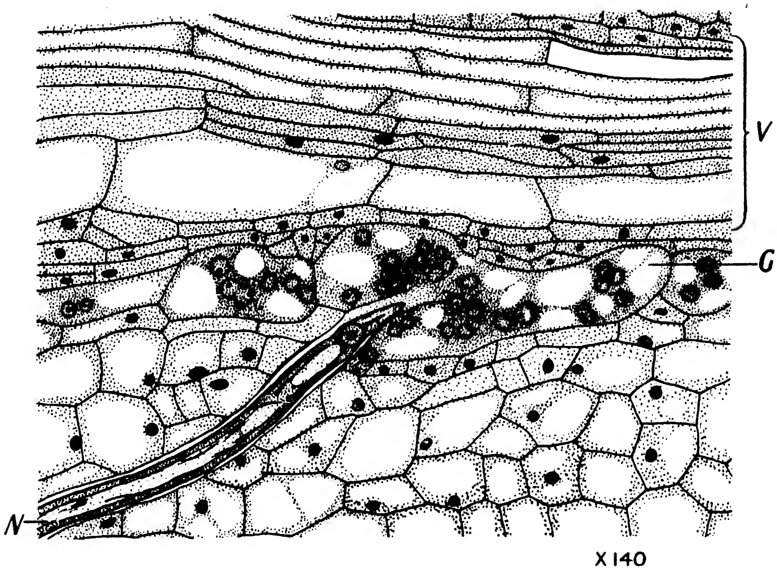


Fig. 4. Young female *Heterodera radicicola* in a section of gall on root of Lahaina cane. N, nematode; G, giant cell with many nuclei; V, vascular tissues. (From H. L. Lyon.)

The development of the male is not quite the same as the female. It seeks the young roots in a similar manner and increases in size but does not become rounded and stationary. When fully grown it seeks the female.

In some roots the galls remain firm in spite of the presence of numerous nematodes. In the sugar cane roots the galls usually break down, especially when situated at the apex, and the root dies back. Often lateral rootlets grow out above the apex, but these soon become infested and the roots cease to function. In the pineapple root the galls also break down and the root decays.

Fungi are nearly always present where nematodes are numerous and they must play some part in the ultimate destruction of the root.

Nematodes have been proved to show a strong tendency to host selection. If a strain of nematodes is reared for several generations upon a certain species or variety of plant they become so strongly attached to that host that they will not change to another. If an area heavily infested with a strain of nematodes which has been reared upon a certain host, A, be planted with a different host, B, the vast majority of the nematodes in that area will die rather than enter the new host B. Or if A and B be planted together B will be very slightly attacked while A will be very heavily infested. Thus B will at first show a strong "resistance" to nematodes, but if grown long enough in that locality may eventually suffer as severely as A.

This problem of host selection is not peculiar to nematodes but is found also among insects. Aphids or plant-lice show this very strongly, as has been demonstrated at the Station with *Aphis maidis,* the corn aphis which carries mosaic disease.

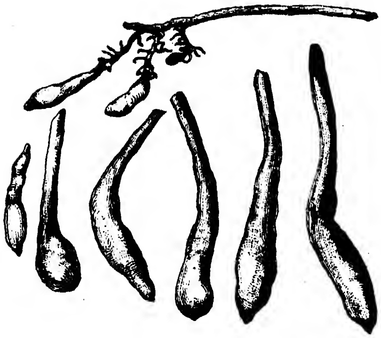


Fig. 5. Galls of *Heterodera radicicola* on Lahaina. (From H. L. Lyon.)

Fig. 6. Galls of *Heterodera radicicola* on Yellow Caledonia. (From H. L. Lyon.)

Fig. 7. Galls of *Heterodera radicicola* on H. 109. (From *Planters' Record,* XX, No. 5.)

Heterodera (especially *H. schachtii*) may remain in the soil in the encysted form for a long period if suitable growing roots are absent. This indicates that the roots produce a stimulus which causes the nematodes to start an active career.

The Beet Nematode, *Heterodera schachtii* (Schmidt)

This species of nematode has not been reported from such a wide area as *H. radicicola* but it is quite possible that it has not yet been distinguished from the more widely distributed species as it can be easily confounded with it. It is only recently that the two species have both been recognized in the Hawaiian Islands.

It has attained its popular name of "beet nematode" on account of the damage it has done to that crop in Europe and America. It has been reported on a number of species of plants, many of economic value.

When living in the roots of beets its life history differs somewhat from *H. radicicola.* As she grows larger the female emerges from the tissues of the plant and remains attached to the root by her head; here, when fully matured, she eventually assumes the hard brown cyst form in which the young develop. In sugar cane the nematode does not leave the tissues of the root but lies surrounded by the root tissues which do not develop into a gall. In this brown cyst stage the eggs or young can remain for a long period if conditions are not favorable, or

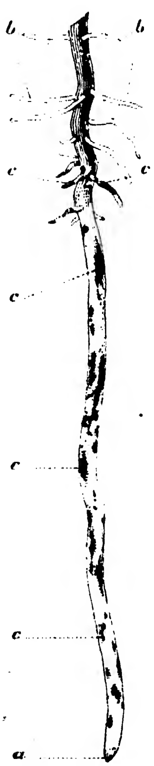


Fig. 8. Root of sugar cane attacked by *Tylenchus similis* Cobb. (After Cobb.)

suitable food is absent from the soil. The eggs in the brown cyst do not always hatch out at once, but a few at a time over a period of many months. A dry heat at 145° F. kills them, even in the brown cyst stage.

Experiments have shown that the young of this species can travel ten feet (about 8,400 times their own length) in two weeks when in search of food. A single female can produce from 300 to 400 eggs and the time from one generation to another is about four to five weeks.

In sugar cane this nematode does not show a preference for the tips of roots but attacks them at any point. Its effect upon the root is to cause the cortex to break down, and the stele to become infected by a fungus which appears always to be associated with it.

As it does not produce a gall on the roots its presence is often overlooked and it can only be recognized by breaking open the cortex.

The Burrowing Nematode, *Tylenchus similis* Cobb

This nematode and its effects upon the roots of cane were described by Dr. N. A. Cobb in 1909. The young enter the cane roots in a manner similar to the two species of *Heterodera* and continue their development among the tissues of the root where one generation will follow another till such time as the root is broken down and made unsuitable for living in. A generation takes from four to five weeks in pot cultures in the laboratory. They produce eggs but the numbers are not known. They remain active all their lives and appear to attack and destroy the surrounding cells and form a chamber in which they live. The roots attacked show no signs of producing galls. The tissues around the point of entrance soon become discolored light red which spreads out and becomes

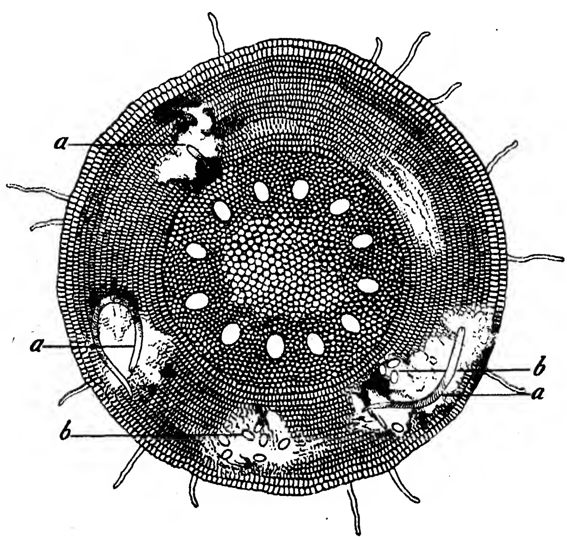


Fig. 9. *Tylenchus similis* in root of D 1135.
a, nematode; *b*, eggs.

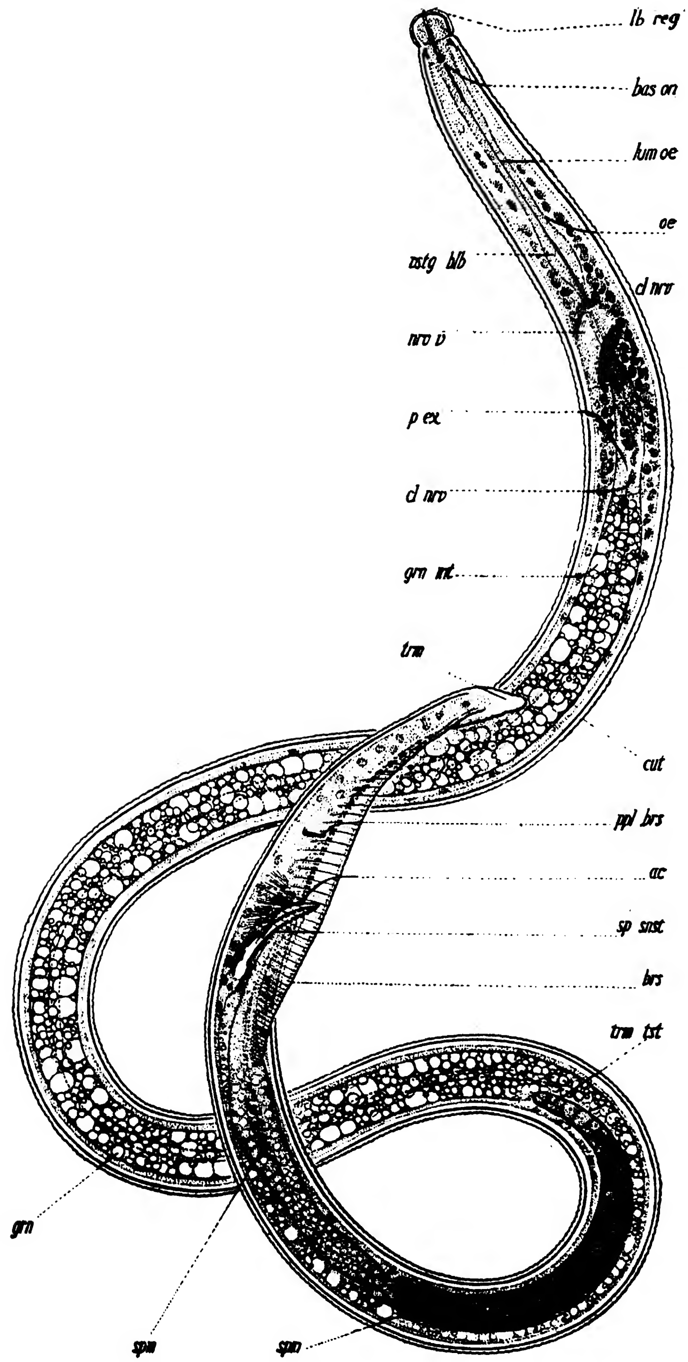


Fig. 10. Male of *Tylenchus similis* Cobb. *lb reg*, lip region; *bas on*, base of spear; *lum oe*, oesophageal lumen; *oe*, oesophagus; *vstg blb*, vestige of bulb; *nvr r*, nerve ring; *p ex*, excretory pore; *cl nvr*, nerve cell; *grn int*, fat granules of intestine; *cut*, cuticle; *trm tst*, end of testi; *spm*, spermatozoa; *brs*, bursa; *sp snst*, spiculum; *ac*, accessory piece; *ppl brs*, bursal papilla. (After Cobb.)

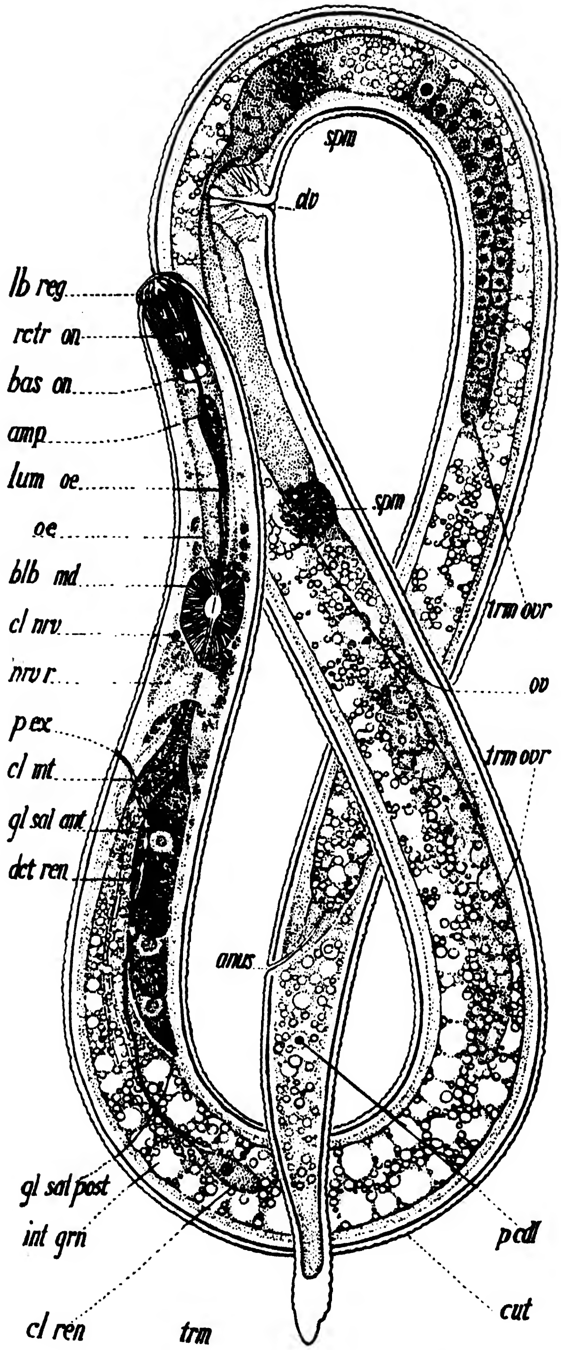


Fig. 11. Female of *Tylenchus similis* Cobb. *rctr on*, retractor muscle of spear; *amp*, ampula; *blb md*, median bulb; *gl sal ant*, anterior salivary gland; *dct ren*, renette duct; *gl sal post*, posterior salivary gland; *cl ren*, renette cell; *trm ovr*, end of ovary; *ov*, ovary; *spm*, sperm; *dv*, vulva; *anus*, anus; *p cal*, candal pore. Other letters same as in male. (After Cobb.)

darker in color. A fungus always accompanies this nematode in the root tissues which, when cultured, has the same color as the discolored tissues. It is possible that the breaking down of the cell walls where the nematodes dwell may be due to the action of a secretion, although it is quite possible that it is due to the direct mechanical action of the moving nematode.

The bad effect of this nematode upon cane roots has been demonstrated in both large and small pot experiments, and clear cases of growth failure in the field have been traced to them. In some cases not an inch of root has been found free from their attack, and all but the most recent roots were dead. In some cases many hundreds of these pesky little beasts have been found in less than an inch of root.

It is difficult to recognize the work of this species once the roots are broken down and have been deserted. The effect is plainest in plant cane of about six to ten months old.

The same species has been found living in nut grass in the Hawaiian Islands and Jamaica, and in banana roots in Fiji.

External or Semiparasitic Nematodes

The nematodes included under this heading differ from the former three in that they do not enter into the cane roots, but pierce the root from the outside and suck the plant fluids. The point attacked becomes discolored in a manner similar to the lesion made by *Tylenchus similis*. The largest, and the commonest, species found in the soil around sugar cane roots is a species of *Axonchium*. In our experiment pots the effect upon the roots is similar to that of *Tylenchus similis* but less severe. The direct damage done by these nematodes is not likely to be very severe, but the lesions made by them give entrance to fungi and so, indirectly, they may play an important role in the root rot problem.

The lesions made by nematodes are more generally infected with fungi than the pits made by insects, snails and centipedes, and it is possible that nematodes convey the fungus spores about with them. The spores of some of the fungi can pass through small earth worms common in the soil without losing their vitality and it is possible that they can pass through the nematodes likewise.

A species of *Xiphonema* is found in the soil in small numbers. This genus possesses a long style which is a very effective weapon for attacking the roots, but as it has only been found in small numbers it can therefore play but a minor part in the root rot problem.

Two species of *Criconema* have been found at times in fair numbers.

Cobb reports eight species of *Dorylaimus* but our researches so far have shown very few.

The effect of all these nematodes on cane roots is similar and they must be responsible for the many little lesions found on cane roots in which no nematode can be discovered. As they have all been found in close association with the sugar cane roots there is strong reason to believe that these constitute their food in the field; in experiment pots *Axonchium* lives on sugar cane roots and increases very rapidly.

Some General Considerations

Localization of Severe Infestation

In the Hawaiian sugar cane fields the severe attacks by nematodes are strictly localized. Although they may be generally distributed in lesser numbers over the whole field, yet it is only in fairly well defined spots that they increase to a severely harmful extent. The reason for this localization appears to be in the soil condition, as the same variety of sugar cane may be grown over the whole area. What this condition is we cannot say at present, but an understanding of it might have practical application. At first it appeared as if alkalinity and acidity might be the controlling factors but further field observations disclosed too many exceptions.

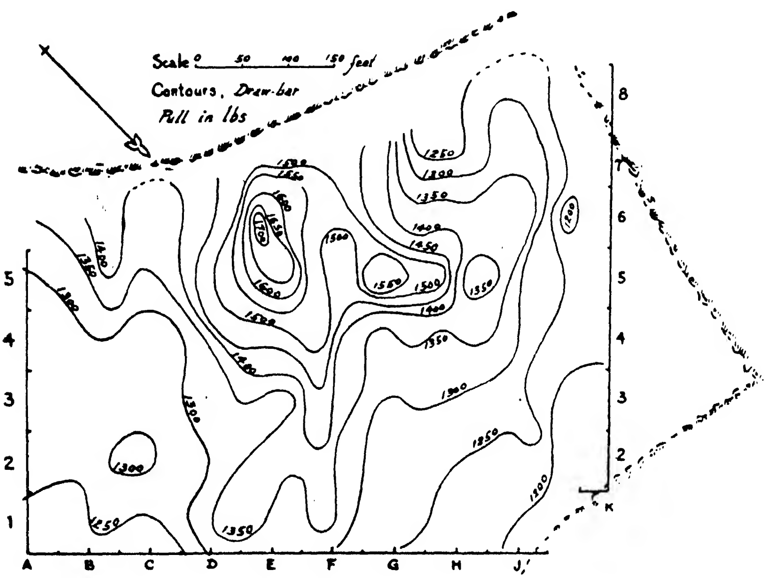


Fig. 12. Lines of equal draw-bar pull over a supposedly uniform field. (After Keen.)

It is possible that the physical condition of the soil may play an important part in this matter. Work done elsewhere may be of interest to us in this matter. In England the drag or pull of the plow has been studied, chiefly in regard to economic speed in plowing. A self-recording instrument is fixed between the plow and the horse or tractor which registers the distance, speed and the pull. This pull depends upon the physical nature of the soil. These records can be plotted and the differences displayed. It was found that many fields which were flat and apparently uniform were physically very diverse; there would be centers of high or low resistance which would graduate out, so that the chart looked like contour lines illustrating elevation. Such charts of some of our own fields, made by such an instrument, or by other means, might throw light on our nematode localization problem and on other matters.

Connection Between Nematodes and Our Lahaina Disease

It has been pointed out by several workers at the Station that "Lahaina disease" is not a single problem but a complex of problems, the causes being several, working either singly or in groups. As has been stated above, nematodes are always associated with fungi and it has been so far impossible to get a culture of nematodes on growing sugar cane roots without the presence of one or more species of fungi or bacteria. In some cases we have found cases of growth failure and root rot where, for practical purposes, no nematodes were found but fungi were present; in other cases neither nematodes nor fungi could be demonstrated to be the active cause, but soil conditions appeared unfavorable. At the Station there are a number of records in which growth failure has been clearly traced to nematodes, and our present work has added considerably to this evidence; the same fields have been shown to have been infected for a number of years in which growth failure has been present in a lesser or greater degree the whole time.

The present nematode survey will have to be greatly extended before we can speak finally upon this subject, but enough evidence has now been collected to demonstrate that a considerable portion of our growth failure is due to nematodes. How far they were responsible for eliminating Lahaina over large areas in the past we cannot say. If patches of Lahaina were planted in some of these areas and the results watched closely we might be able to draw more accurate conclusions.

One of the most vital questions on many of our plantations today is whether we shall ever have an H 109 problem similar to the "Lahaina disease" problem. This we cannot say at present, but anything that elucidates the latter will enable us to foresee and, perhaps, ward off the former.

The nematode problem is not confined to the sugar industry but is an important one to the pineapple industry and, perhaps, even a greater one to other forms of agriculture, such as truck gardening. That these small and obscure animals are a limiting factor in growing many sorts of vegetables is evident to anyone who has tried to grow them in his yard. Without nematodes we should get quite one hundred per cent more for our labor than we do.

Problem of Control

X

From an economic standpoint, this question is the most important of the phases of the nematode problem, and, unfortunately, so far no permanent form of control has been discovered. Even temporary palliatives have as yet been unsatisfactory, chiefly owing to our lack of knowledge of the life history, habits, and senses of these small creatures whose lives are passed in the soil.

Resistance, Changes of Varieties and Agricultural Methods

This question has been greatly obscured in the past because the strong "host selection" factor was not appreciated, and much contradictory evidence was accumulated which has only recently been understood. Undoubtedly there are some

varieties of plants which are less susceptible to attack and others which are less able to withstand attacks. The damage to sugar cane is proportional to the number of nematodes attacking and the power of the plant to send out new roots. Thus relief could be looked for along two paths, viz., varieties which are resistant to attacks or which have vigorous root systems, and agricultural methods promoting the root growth. As the destruction of the roots brings about starvation of the plant so any small degree of lack of water will be felt severely by nematode infested plants, thus the water-holding power of the soil is important. Organic manures around the roots of infested plants should be of service.

It has yet to be shown that the host selection principle plays any part with our different varieties of sugar cane, but the fact that a change of varieties has shown good results makes such a thing probable.

From what we know of the life of our nematodes at present clean fallow is of little value and this was well shown by an experiment at Waipio where a plot of land infected by nematodes was divided into two parts, one sown to Jack beans and the other left clean fallow for a season. Both plots were then planted to Lahaina cane and the one planted to Jack beans gave a very marked increase over the one left to clean fallow. It is possible to explain this as follows: The nematodes in the clean fallow plot remained dormant until it was planted to cane, but the nematodes in the plot planted to Jack beans were stimulated to activity by the growing bean roots but refused to enter them and so perished.

Trapping

This method of control has been as successful as any and is founded upon a knowledge of the life history of the nematode. It is only applicable to those forms which enter into the roots. As it takes about five to six weeks for the nematodes to mature it is possible by planting a crop which they like and by destroying it before the nematodes have time to reach maturity, to trap and destroy them before they can produce another generation. By repeating this process twice or three times the soil can be greatly relieved from nematodes. By what we have said re host selection it is best to use the same plant for the catch crop as was formerly grown on the land. Some of the good experienced by this method may have been due to rotation and not to trapping; the nematodes may have hatched and died, but not entered the "trap."

Rensch in Germany reports that he has extracted two substances from roots which, when placed in the soil, causes the nematodes to hatch out. Such substances placed in clean fallow soils would soon clear them of nematodes. If this be correct and the substances can be produced on a commercial scale then the greatest advance has been made towards nematode control.

Poisons

A great amount of work has been done along this line but so far no poison has been found which is effective and economical on a plantation scale. The Station is experimenting with certain poisons so that if they are efficient they will give relief to the worst spots even if they be not applicable to large areas.

Biological Control

Having been successful with the biological control of insects in the Islands it is natural to consider such a method for controlling nematodes. Unfortunately our knowledge of nematodes is not so great as it is of insects or perhaps we could handle the problem in a similar manner. Cobb and other workers have shown that certain nematodes are predaceous and feed upon other nematodes. So far as we know at present we have four species of a predaceous genus (*Mononchus*) in the Islands, but the only one we have found in our present work is *Mononchus brachyuris,* and that appears to be confined to damp soil or soil

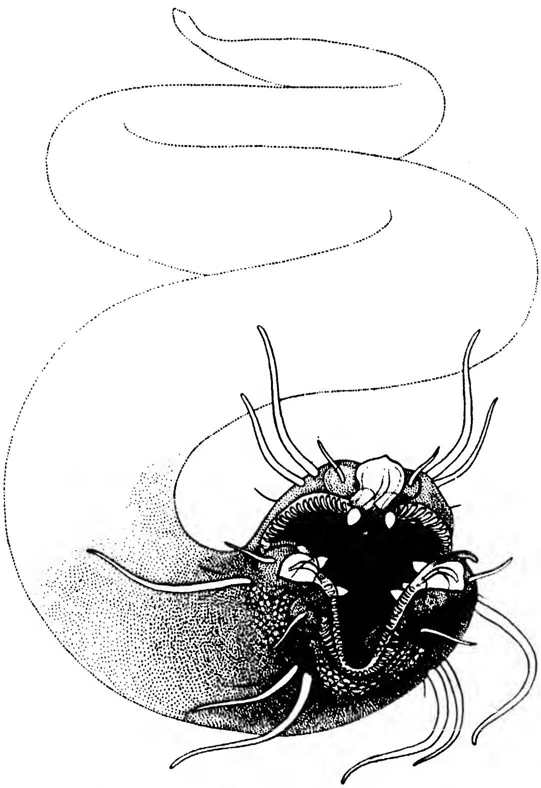


Fig. 13. A predacious nematode. The front view of head is correct; the body is more imaginary, but nearly correct. (After Cobb.)

that has been heavily treated with organic fertilizer. In such localities where this nematode is found other nematodes are not numerous. Whether other species could be found elsewhere which would live in our other types of soil is a point worth considering. There is a record of a fungus-killing nematode (*Arthrobolys oligospora*) which should be investigated. What other soil-inhabiting animals or plants attack nematodes we do not know.

The above is a very short and partial presentation of the nematode problem in Hawaii. It is of great interest to the agriculturist and the biologist, but from

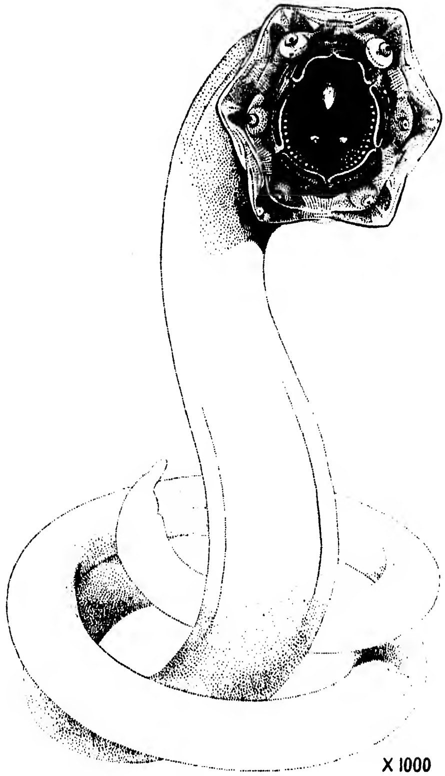


Fig. 14. Another predacious nematode. (After Cobb.)

its complex nature difficult to explain briefly. If the reader should find it uninteresting it is not on account of the subject but because the writers have failed to present the problem clearly.

The Soil Fauna of Hawaiian Cane Fields

By R. H. Van Zwaluwenburg

This article aims to point out the various kinds of animals found in Hawaiian cane soils, their numbers, and their relation to the cane plant. It is preliminary in character, for the work is still going on. Discussion is confined to such forms as can be seen with hand-lens or naked eye; in other words, to what may be termed the "macrofauna," and does not include the field of nematode worms.

General Observations

The bulk of the subterranean animal life is contained in the upper 9 inches of soil, although individuals are found below that level whenever physical con-

ditions are favorable. The top 9 inches also contain over 50 per cent of the mass of cane roots.

The main factors affecting animal abundance in soil are: (1) ample food supply, which may consist of growing plant-tissues; decaying organic matter or, for parasitic and predaceous forms, animal food; and (2) favorable moisture content. An irrigation will cause the majority of the insect inhabitants of the soil to move upward from the lower levels, but the position of the centipedes, mites, etc., seems to be but little affected by additions of moisture. Myriapods and insects alike increase in numbers during the rainier months of the year.

The most numerous groups of animal life in the soil are: (1) myriapods, including centipedes and millipedes; (2) insects; and (3) arachnids, including the spiders and mites. Groups occurring in much fewer numbers are the larger worms, the crustacea (including sowbugs), and the molluscs, which include the snails.

The economic importance of this soil fauna, aside from such definitely injurious insects as the *Anomala* beetle, has yet to be determined, and its possible complicity in growth failure (root rot, Lahaina disease) makes its study of value. The evidence against some of the commoner forms will be discussed below. Not all the soil inhabitants are injurious; the common earthworm (unfortunately rare in the irrigated plantations) does an enormous amount of good in slowly bringing up soil from the lower levels, and in breaking down organic matter. Likewise, a very common millipede is no doubt of benefit in breaking down old roots.

Our results are divided for convenience according to three types of land, as follows:

A. Clean fallow; land which had no crop, and few or no old cane roots.

B. Root-fallow; land containing old cane stubble and many roots, but no growing crop.

C. Growing-cane land; either plant or ratoon. In the latter case it is partly root-fallow in nature due to the decaying roots of the previous crops.

Comparative Abundance and Vertical Distribution

Growing-cane land has nearly four times as many animal inhabitants as bare-fallow, and over one and one-half times more than root-fallow land (see Fig. 1). The numerical ratio is as follows: clean-fallow, 10; root-fallow, 23; growing-cane land, 37. The insects outnumber all other groups in each type of land, although in root-fallow the myriapods are nearly as numerous as the insects, their increased numbers here being explained by the preference of millipedes for decaying roots (see Fig 2).

In clean-fallow the bulk of the animal life is normally between 3 and 7 inches; in root-fallow between 5 and 9 inches; and in growing-cane land between 1 and 5 inches, which is the depth at which the mass of growing roots is greatest (see Fig. 3).

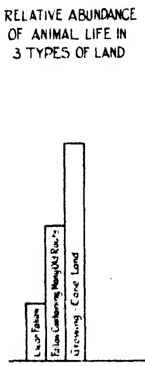


Fig. 1.

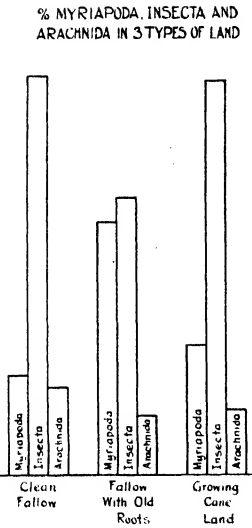


Fig. 2.

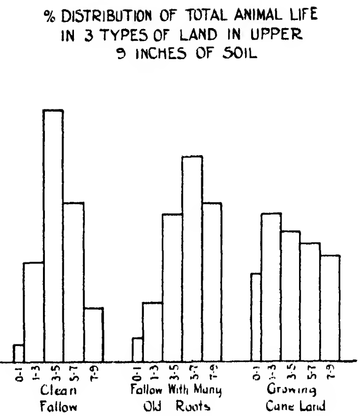


Fig. 3.

The groups of animal life are most numerous at the following depths in the three types of land:

Myriapods:

Clean-fallow, most numerous at 3-5 inches.
Root-fallow, most numerous at 7-9 inches.
Growing-cane, most numerous at 5-7 inches.

Insects:

Clean-fallow, most numerous at 3-5 inches.
Root-fallow, most numerous at 3-5 inches.
Growing-cane, most numerous at 1-3 inches.

The arachnids are very evenly distributed to 9 inches in all three types of land.

Injury to Cane Roots

In most cases the injury to the roots by the soil animals takes the form of a round pit, varying in diameter with the size of the attacking species. Almost all such injury is confined to the cortex and seldom penetrates into the stele. A favorite area of attack is the one-half to one inch of root free from root hairs immediately behind the growing tip. Not infrequently the root-cap itself is pitted.

Several of the animals commonly found in cane soils have injured cane roots under laboratory conditions, and probably do so in the field to some extent. Growth failure has been observed where no injury by the macrofauna was visible, and on the other hand, vigorous stools have been seen which had an enormous amount of pitting on the roots. The possibility of pathogenic fungi or bacteria gaining entrance through cortex wounds is recognized, and is the subject of experiments now under way. Another possibility is that under favorable conditions a cane stool can survive an amount of mechanical injury from soil animals which in the presence of unfavorable physical or chemical conditions would tip the balance sufficiently to result in growth failure.

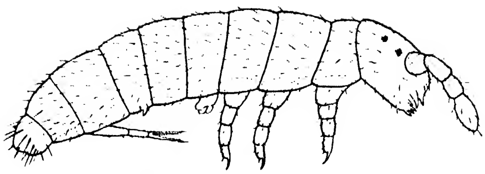


Fig. 4. Collembolous insect exceedingly numerous in all types of soil. It has biting mouth-parts, and under laboratory conditions makes pits in the tender parts of cane roots. X 100.

In growing-cane land the potentially injurious forms average about 66 per cent of the total animal life present, exclusive of the nematodes. The following have fed repeatedly upon freshly cut cane roots in the laboratory:

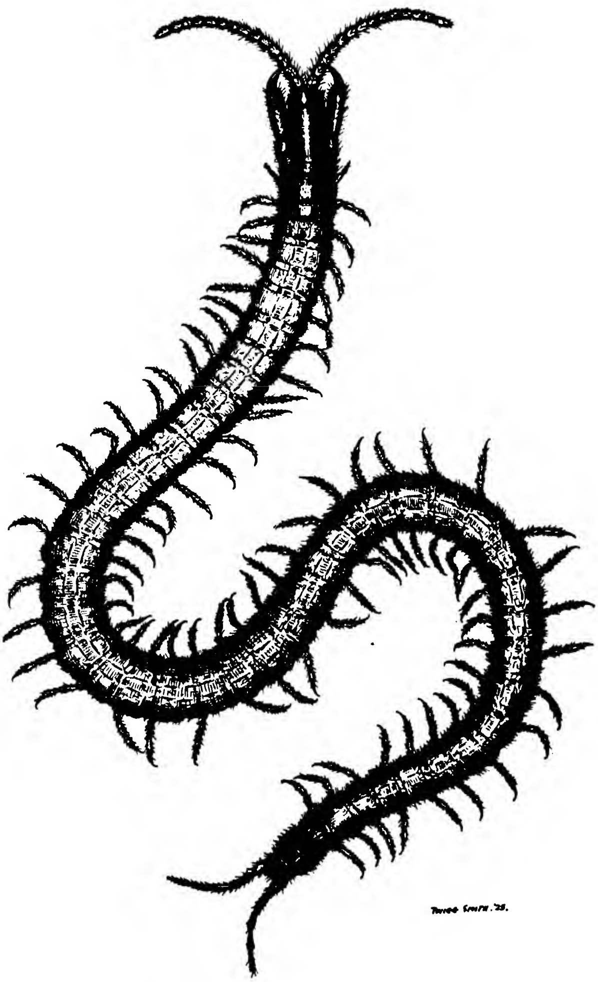


Fig. 5. *Mecistocephalus maxillaris.* A common centipede which forms pits in healthy root tissue. X 8.

1. *Collembolous insect* (Fig. 4). An unidentified insect averaging about 1/25 of an inch long, related to the snow-flea of the mainland. It makes round pits, very small in diameter and comparatively shallow. Suspicion points most strongly to this insect as a possible factor in growth failure, due to its widespread and abundant occurrence. It forms about 55 per cent of the total animal life in soil in which cane is growing. Part of its food is probably decaying vegetable tissue since it breeds abundantly in land containing old cane roots.

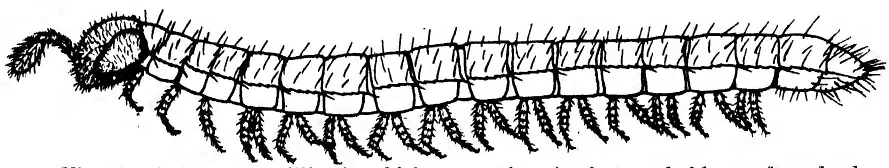


Fig. 6. A common millipede which can make pits but probably prefers dead roots to living ones. X 35.

2. *Centipedes* (Fig. 5). Two species of centipedes varying in size from ½ to 1¼ inches form comparatively large, deep pits in the roots. One of these, *Mecistocephalus maxillaris*, was first shown by C. E. Pemberton (see *Planters' Record*, January, 1925) to produce these pits, and due to its abundance at Honokaa, it was early suspected as a possible factor in growth failure on that plantation. This species when adult has 48 pairs of ambulatory legs. The other centipede has 36 pairs of ambulatory legs and causes pitting indistinguishable from that of *M. maxillaris*. Both species together form about 5 per cent of the total macrofauna of growing-cane land, and have been found on all of the cane-growing islands.

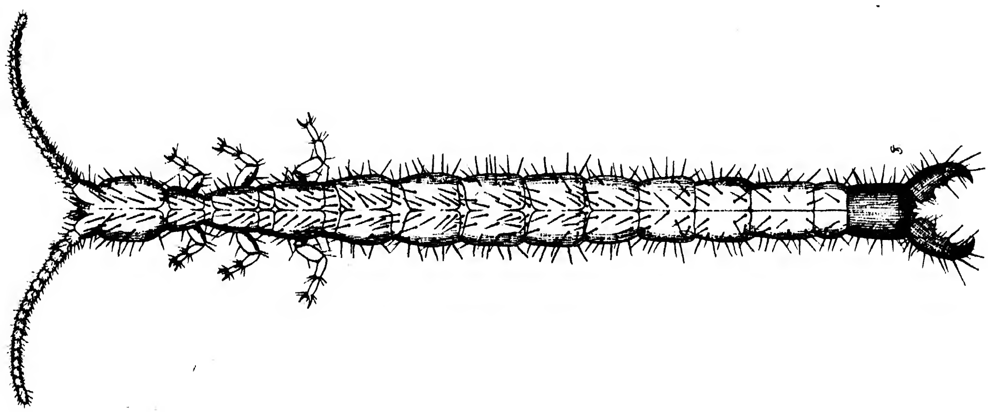


Fig. 7. *Japyx sp.* An insect which in the laboratory has made pits in healthy cane roots. X 50.

3. *Millipedes* (Fig. 6). A small white millipede about ¼ of an inch long is sometimes very abundant, especially in land having many old roots. Its principal food is probably decaying roots. On fresh roots in the laboratory it sometimes makes rather wide pits, but generally rasps off the cortex tissue. It constitutes about 4 per cent of the fauna in growing-cane land.

4. *Japyx* sp. (Fig. 7). This is a white insect about ⅛ of an inch long with a chitinized forcep-like organ at the end of the body. Its injury to roots in the laboratory takes the form of irregular shallow pits. It is seldom common, and constitutes less than 1 per cent of the fauna of growing-cane land.

5. *Caecilioides baldwini.* This is a very small snail, similar to a species which is said to be involved in growth failure in Louisiana. It forms a clean round pit on fresh roots in the laboratory. We have not seen it in the field in enough numbers to account for growth failure. It is so rare that numbers sufficient for experimental purposes were obtained with great difficulty, and then most abundantly in abandoned pineapple fields under rotting leaf-sheaths.

Exotic Trees in Hawaii

By H. L. Lyon

It appears that young Hawaiian lavas make a suitable substratum on which the native plants will grow luxuriantly, providing they are supplied with the necessary moisture. When these same lavas disintegrate and decay into finely divided materials, however, the residual soils invariably contain, as products of decomposition, soluble, mineral compounds which are poisonous to the native plants, and consequently on old soils these plants are always delicate and prone to die off upon the slightest interference from man or the foreign animals and plants which he has introduced.

The creation of new forests to replace our disappearing native forests is obviously one of the most vital problems confronting the Territory. To solve this problem, we have got to find trees that will grow on our watersheds despite the adverse soil conditions existing thereon. The only practical method of procedure is to determine by experiments the various species of trees, shrubs, etc., that will grow even though these poisons are present in the soil. This was the first step in forestry work undertaken by the department of botany and forestry of this Experiment Station upon its inception.

We have introduced exotic trees from many parts of the tropics and subtropics and planted them in as many localities as possible in the Islands to determine their reactions to the existing conditions of soil and climate. As was to be expected, a very large percentage of the trees planted in our experiments failed to make a normal, healthy growth. Some succeed in one locality but fail in others, but a few seem to thrive in every locality in which they are planted. It is trees of this latter class that we shall recommend for general use in our forest plantings. While our experiments have really been in progress but six years, still we have already obtained sufficient data on certain species of trees to warrant an opinion on their merits as components of the forests which we wish to build on our watersheds.

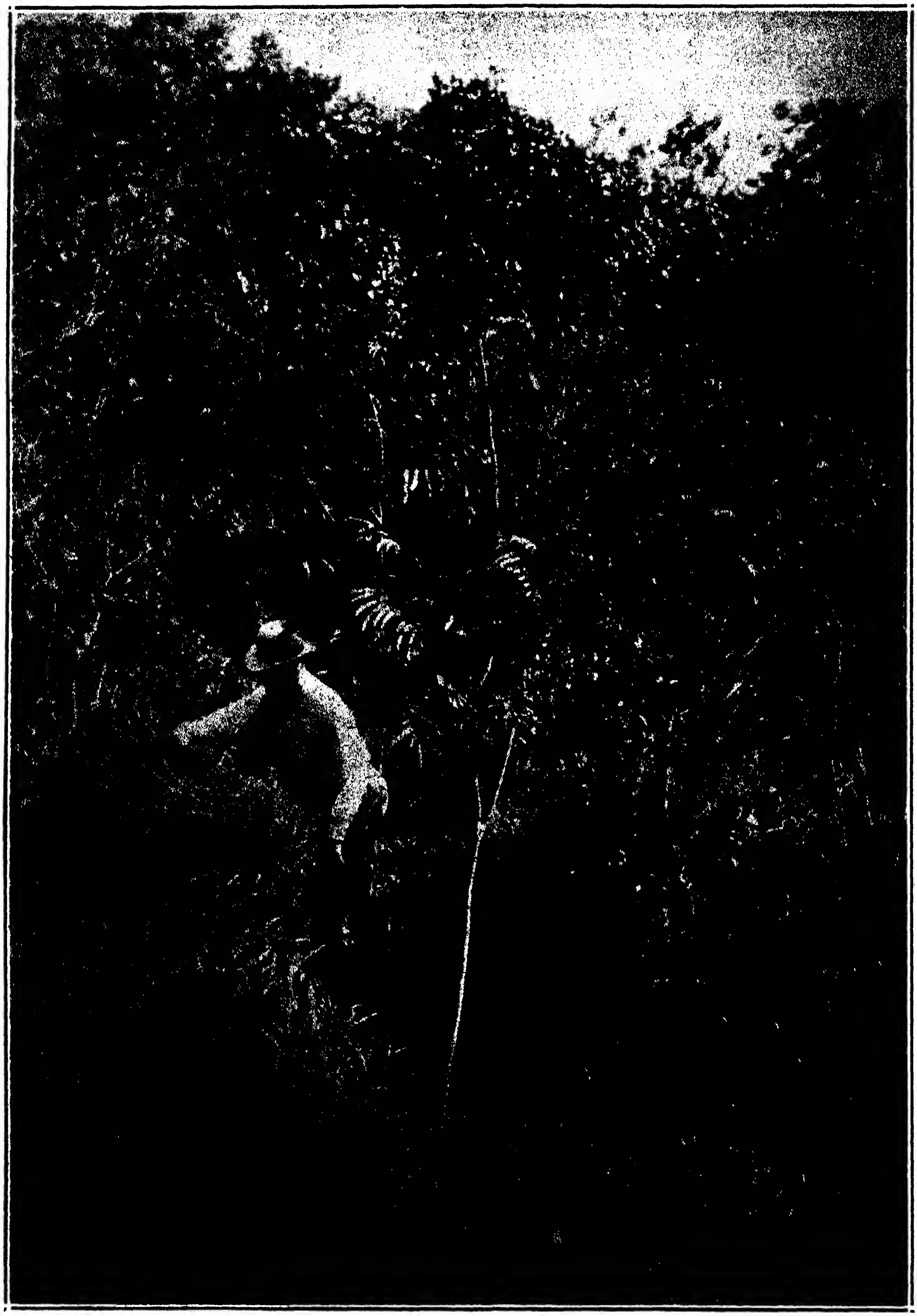


Fig. 1. *Albizzia moluccana.* This photograph was taken in January, 1922. At that time, the tree had been in the ground just one year. It was a seedling about three feet tall when planted out.

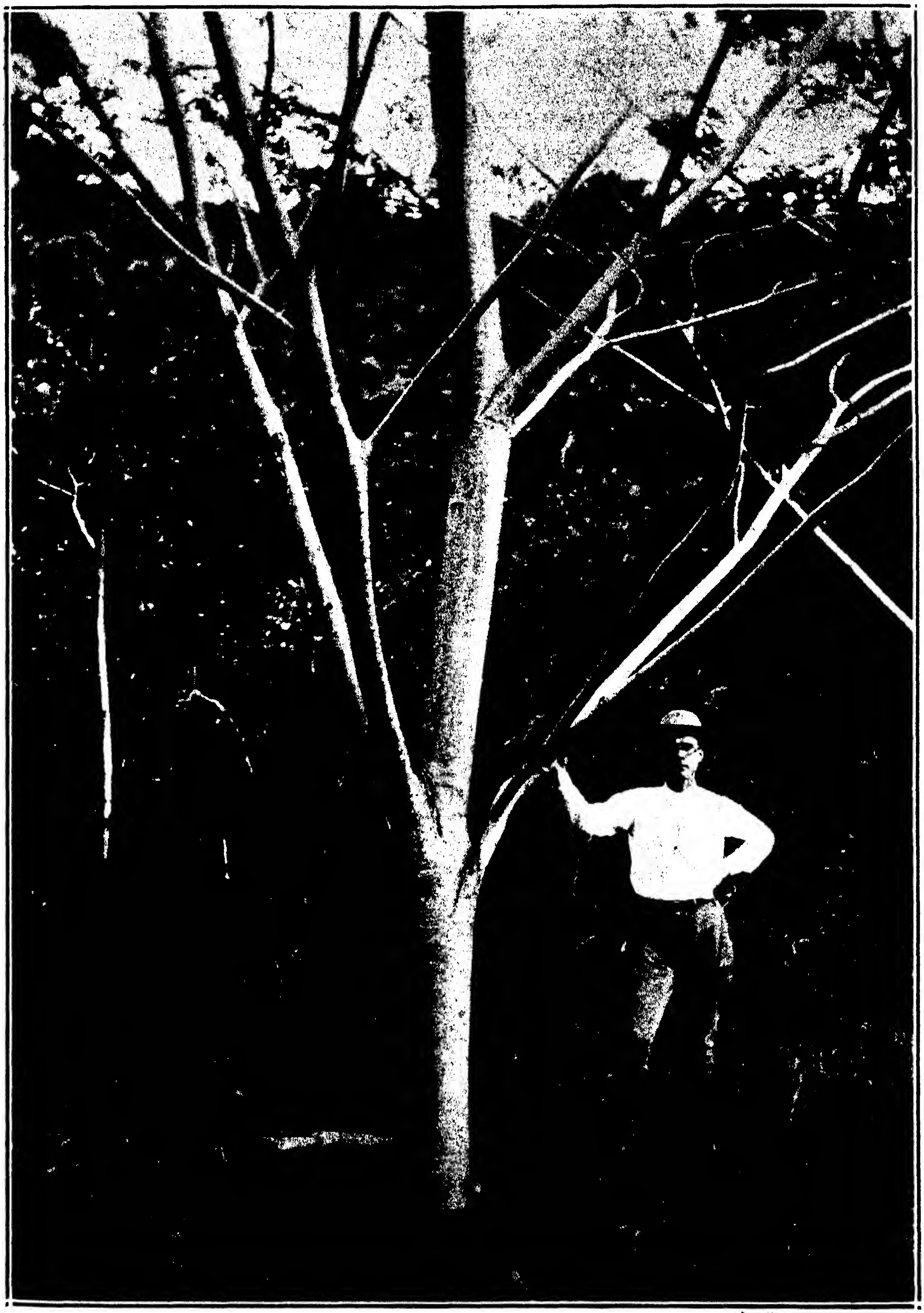


Fig. 2. *Albizzia moluccana.* The tree shown in Fig. 1 as it appeared in February, 1926, when six years old from seed. It should be a profitable fuel crop to plant on lands otherwise unproductive.

In a series of articles appearing in *The Record* we shall describe and illustrate some of the exotic trees which are showing up well in our various arboretums and forest plantings.

Albizzia moluccana: This leguminous tree from the Malayan region has, on the average, made more rapid growth than any other tree in our cultures. It is said to prefer a heavy soil in a moist situation and to thrive up to 4000 feet elevation in Ceylon. It does not cast a heavy shade, hence fosters a vigorous undergrowth. Some authorities report that it is a short-lived tree, but reproduces freely, always maintaining a good stand on the land. Troup, in his *Silviculture of Indian Trees,* says of this species:

A very large fast-growing Malayan tree with light foliage and a straight, clean, smooth, grey bole, branching high up. It is largely grown in Ceylon and Java as a shade to coffee, and is worth cultivating as a quick-growing shade tree for other crops requiring light shade, as it is said to possess soil-improving properties. It has recently been grown on land cleared for tea in Assam, where in the Towkok garden, Sonari, Sibsgar district, trees four years from seed were reported in 1913 to have grown 46 feet in height with a girth of 2 feet, 9 inches at 3 feet from ground-level. Plantations of this tree have recently been formed in the Andamans, where it grows well even in exposed situations and is not affected by wind. Plants from seed sown in December, 1912, attained by 1916 a height of 30 to 35 feet and a girth of 1½ to 2 feet; those on the soil of cleared evergreen forest attained in the same time a height of 40 to 45 feet and a girth of 2-3 feet at 3 feet from ground-level. A tree in the Royal Botanic Gardens, Peradeniya, Ceylon, eleven years old, was 125 feet high and nearly 11 feet in girth at 2 feet from the ground. In Ceylon, the pods ripen in May-June; the seeds are small, about 1,200 weighing 1 oz. The wood is soft and light, and suitable for tea-boxes and planking. Owing to its rapid growth, it should be worth planting for this purpose in suitable localities.

This tree is doing remarkably well in the Manoa arboretum, as may be seen from the photographs reproduced herewith. It has also made very good growth in our plantings in the Halawa-Niulii forest area around 2000 feet elevation. The wood is very brittle and trees planted in exposed situations are very apt to be broken by the wind. If planted in groves, however, they weather heavy storms with the loss of branches only and these are soon replaced by new growths. It is quite evident that this is going to be a very useful tree in our forest plantings below 3000 feet elevation, and will enable us to quickly cover denuded areas with vegetation having considerable vertical depth. Unfortunately, the local-grown trees are as yet producing but few seeds and consequently we must secure most of our seed from abroad. This is proving a rather difficult matter to accomplish.

A Review of Soil Investigations Pertaining to Growth Failure of Sugar Cane*

By W. T. McGeorge

The most of our work on this plant failure problem has been along two rather definite lines: one covering the acid soils and the other the more alkaline soils on the irrigated plantations. The acid soil work has been principally upon the toxicity of aluminum salts with a small amount of work on the manganese and iron salts. The basis for this aluminum work is that carried on in the states in which it has very definitely been tied up with corn root rot; in Austria where it has been tied up with sugar beet root rot, and also in India where it has been found to be associated with the wilt of cotton. When we started our investigation there had been no definite attempt made to classify soils in which we might expect to find aluminum toxicity; so the first work that we did was to select a series of soils covering the range found here in the Islands and to determine which of these soil types contained soluble forms of aluminum. This series ranged from a pH of 4 to a little above 8 and we found that all the soils more acid than that represented by a pH of 5.8 contained soluble forms of aluminum and were classified as possibly being toxic. Since this work was completed there has been a paper published from the University of Wisconsin covering a similar study which has confirmed our work, but also has gone into the soil study more extensively. They studied the solubility of aluminum salts from an acidity of pH 3.5 to an alkalinity of pH 10, and found the lowest solubility of aluminum at pH 5.7 which is very close to our 5.8. On the other hand, they found that the solubility of aluminum increases with alkalinity, so that when you get up to a pH of 8.5 to 9 you have very large amounts of aluminum coming into the solution as alkaline salts. We have been figuring on taking up this phase of the work for some time but have never felt that there was any possibility of toxic aluminum in the alkaline soils, because all our alkaline soils are very high in lime and calcium aluminate is a very insoluble compound. So we never felt that we could anticipate any toxic aluminum in our alkaline soils, but that is one phase of the work that we intended to go on with. This work at Wisconsin was carried on in salt solutions so that the figures which they give out do not necessarily mean that alkaline soils would contain soluble aluminum compounds. There is another phase of our work on the acid soils that seems to me to be very important. In our highly organic soils, such as those from Olaa down the Hamakua Coast to Pacific Sugar Mill, the acidity is not so high as it is in our red clay soils but the toxicity seems to be much more active there. The soluble amounts are not so high, but the availability seems to be very high and I think that is one reason why we find considerable amounts of toxicity in some of those less acid Hamakua soils.

* Presented at an Experiment Station staff meeting January, 1926.

After this soil work our next step was to determine whether aluminum salts were toxic towards sugar cane. In this part of the work I think we proved beyond question that they are toxic. There have been several criticisms of the methods used for determining the toxicity of aluminum salts. One of these is that some investigations have failed to take account of the fact that wherever you have aluminum salts in solution you necessarily also have acidity or hydrogen ions. On this basis they contend that toxicity may be due in part to acidity. We carried on experiments considering this criticism and found the acidity itself was not toxic toward sugar cane, but in the presence of aluminum salts there was an unquestionable toxicity and we obtained this toxicity in concentrations of only 10 parts per million, which amounts are often found in our soils here. There has also been some criticism that aluminum toxicity is nothing more than a phosphate or other plant food deficiency. To answer this we ran some experiments in which we left off phosphate entirely; we also left off lime and potash and on growing the plants in these cultures there was no stunting in growth from leaving off these plant foods. The deficiency of nitrogen was the only one that stunted the plant. Along with this series the aluminum salts showed very strong toxicity even in the presence of these nutrients so that we feel as far as we have gone that there is no question but what there is a direct toxic action of aluminum towards sugar cane.

Then, our next step was to carry on some pot experiments. For this purpose we selected two distinctly different acid Island types, the acid clay and the acid organic soil and were able to show rather definitely that these soils respond slightly to lime and very remarkably to heavy phosphate and potash applications. Both of these treatments have been considered in the States as being corrective methods of reclaiming acid soils. In the early work in the States lime and phosphate were extensively used in building up these acid soils, but some later work has shown that certain very well defined cases of corn root rot have responded only to potash applications and that phosphate and lime neither singly nor together would reclaim these areas. So I think there is a great deal to be learned even yet about the nature of aluminum toxicity. One of the principal conditions found to be associated with this toxicity is the accumulation of these metals at certain vital points in the plant. Dr. Hoffer has associated this with the failure of corn in the Middle West. We have applied his tests quite extensively with many positive results, indicating that on the whole our two problems are very closely related. He has found that potash seems to prevent these accumulations of aluminum and iron in the corn stalk. We carried out a test of this nature at Honokaa in which we compared the stalks of cane treated with potash applications and the untreated. Both the qualitative and quantitative determinations of iron and aluminum showed that these elements had been greatly reduced by the potash in the internodes and the nodal joints where the accumulations seem to take place.

There is still one phase of our soil work that I think should be more definitely studied, and that is the fact that we do not seem to get immediate response to lime. I think that response will come after a period of years and I do not believe a permanent reclaiming of these acid soils will ever be brought about without the

application of lime along with these potash and phosphate treatments which seem to give more immediate response. We find a similar relation in alkaline or neutral soils in some of our experiments where we have added aluminum salts to try and produce aluminum toxicity. On the Station soils we have failed to reproduce it with reasonable amounts of aluminum salts, even though we get the acidity, showing that there are certain factors associated with aluminum toxicity in acid soils which are not formed immediately on making fertile soils acid. In taking red clay soils such as we have in the upper fields of the Oahu Sugar Company it is very easy to reproduce aluminum toxicity in these soils, and I think it is because they are low in lime, phosphate and potash and soils which do not contain very large reserve amounts of these necessary elements. Another very important thing is that when we reach the toxic acidity in these Oahu Sugar Company soils we find that the solubility of lime has been increased about four or five times. This seems to indicate how rapidly lime would be leached from acid soils and how quickly they would soon reach the stage where aluminum would begin to function as a replaceable base and become toxic. That is, where the soil contains appreciable amounts of lime this element will play the principal role of replaceable base; but as soon as aluminum or iron commences to act as replaceable bases there results the soluble salts, which are toxic. I think this covers the aluminum work pretty well.

The work which we have done on the irrigated or alkaline soils has been principally on the effect of saline accumulations from irrigation water. This work is by no means a new subject. I think Maxwell, Eckart, Peck and Burgess all devoted some time to it. Burgess confined his work almost entirely to black alkali. We began work on this phase of the problem after the soil work which has just been spoken of, showing that we could only expect aluminum toxicity in acid soils. At this time Dr. Lyon had a small experiment down in Field 14 at Ewa where he had put in some Lahaina cane and it was making practically no growth at all, yet was surrounded by perfectly good H 109 cane. The first thing we did was to remove the soil solution from this soil and make an analysis of it. The analysis of the soil solution showed a very high concentration of soluble salts from the irrigation water. We then went to quite a number of areas on this island where Lahaina was still growing or had failed and found that there was a higher concentration of soluble salts in the soil solution in the fields in which Lahaina had failed. The next thing we did was to take this soil from Field 14 at Ewa and subject it to a series of leachings before planting to Lahaina cane. We found that the growth of Lahaina was materially aided by leaching out these soluble salts. Then by analyses of the plants we were able to show that there had also been a material change in the composition of the Lahaina. That is, normally the plant contains large amounts of sodium in the roots and small amounts of potash, while in the tops the potash is very high and the sodium very low. We found that this ratio was materially changed by these high concentrations of soluble material and that by leaching and lowering the concentration in the soil solution we were able to improve the growth of Lahaina and at the same time the analysis of the plants showed an approach toward normal composition. The next phase of our work was to carry out an extensive series of water plant cul-

tures in which we compared the growth of H 109 with Lahaina. The analysis of this soil solution from Field 14 at Ewa showed that the principal salts present in the soil are the calcium, magnesium and sodium chlorides and the sulphates of these same elements. So we made up an extensive series of cultures, varying in concentration using these salts separately and while there was some difference between the effect on H 109 and Lahaina there was not sufficient difference to account for the difference found in the field. On the other hand, when we combined these chlorides in the same ratio in which they were present in the soil solution we were able to show very definitely that the combined chlorides were far more toxic toward Lahaina than H 109. I think this fact shows very definitely why H 109 grows better on many of our irrigated fields than Lahaina does. It is very easy to explain the effect of these conditions on plant growth because when the plant root absorbs a salt it does not absorb the salt as a whole, but only the ions. Also when it absorbs a soluble material it cannot return this to the soil solution again by diffusion. That is to say, the plant root only gives off water and carbon dioxide but may absorb any ion of a salt present in the soil solution. On the other hand, many plants exercise a selective action in absorbing ions from the soil solution, which property gives them greater resistance. In fact, it is very easy to find several explanations which would account for the disturbance which seems to follow the conditions mentioned. I think that is about all I have to say on these points.

Discussion

Agee: You spoke of the question of liming acid soils. At this time some of the plantations on Hawaii are spending large amounts for lime and other plantations nearby are spending nothing. The feeling is that if lime is a good thing they should all put it on, or if nothing is to be gained from its application that the expense now being incurred by some plantations could be saved. What would your recommendations be in such a case?

McGeorge: The question in my mind is, what will be the condition of those fields fifty years from now? The Honokaa lands, for example, are very deficient in available lime. Under those conditions you find aluminum salts acting as replaceable bases. I realize, and I have admitted right along, that experimental evidence is all against the economic value of lime on those fields; but at the same time there is no question but what lime will bring about the conditions which operate against the activity of aluminum salts and its use is theoretically sound. It is just a question of what they will be fifty years from now. There are several cases where they had evidence of a better growth of Lahaina after the application of lime; for instance, the work of Hartman, chemist at Onomea Sugar Company, under the management of Mr. Goodale. Then there is Mr. Lidgate's experiment at the Hamakua Mill, but outside of a few mauka fields on Kauai I have not seen any indication that there is any immediate economical return from liming.

Agee: It certainly makes it a very difficult question to have this difference between theory and actual field test.

Lee: Don't your pot experiments show a response from liming, Mr. McGeorge?

McGeorge: Yes. Our experiments on Honokaa soil were on soil from Field E.

Lee: I was wondering if a more intimate mixture of lime such as in the pots might give a quicker result in field test.

McGeorge: We got some better results, but in the field experiments, thus far I can see no notable response. It is a queer thing about this aluminum toxicity problem. I do not believe that it is or will be a factor in the good fertile soils. Most of our acid soils are deficient in lime, phosphate and potash, which deficiencies seem to operate to make aluminum more toxic.

There is still the possibility of ferrous iron. I think that this may be one of the factors at Olaa. Most Olaa soils are not acid enough to contain aluminum salts in soluble forms but they contain quite a bit of ferrous iron and in a number of stalks which I have examined I always got a good strong test for these accumulations of iron. Then again we have a number of areas at Waimanalo where there seems to be a growth failure of some sort. I found a very interesting relationship there in Field 23. There is one low spot which is just alongside of a knoll and on this knoll the plants are entirely normal. I took a stalk from this knoll and one from down in the lower spot where the growth failure was so bad and drainage poor and made a test for these accumulations. The good cane from the knoll where the drainage was good gave a negative test and the cane in the low spot where the growth failure was very pronounced gave a very strong test. Now, according to what Mr. Beveridge told Mr. Stewart those areas began to pick up after the cool weather and the rains came on. The last time I was there I noticed very distinctly that in the drainage ditches running through the fields the water was seeping out and the ditches were lined with a coating of oxidized iron. The iron was being precipitated out of these leachings showing very distinctly that one of the changes taking place in the soil is the leaching away of the ferrous iron. Whether this is the cause of the poor growth I do not know, but it is associated with the conditions there. That is one phase of a problem which we are preparing to take up, a study of the oxidation and reduction in the soils to bring about a better oxidizing environment in some of these low areas. I have grown some cane shoots in a solution containing colloidal aluminum hydroxide to see if these colloidal materials, which you are sure to have in a maximum amount in a poorly drained soil, would have any effect on the root growth and I found that the roots were greatly stunted by coming in contact with the colloids. I think it was the coating of colloidal material on the roots which had prevented proper respiration. After the plant had grown for a month or so in this solution I transferred it to tap water and the roots are growing along serenely. It was just a temporary effect and not a toxic effect.

Newcombe: Do you know whether the same roots started up growth that were already there?

McGeorge: Yes, the principal difference was in the secondary roots. Yes, there were new roots forming there, too. The roots were not dead, they were simply not growing.

Agee: Has there been any indication of soil trouble in connection with the lower land of the Oahu Sugar Company which could have affected and accounted for the failure of Lahaina?

McGeorge: The only thing was that the areas which Mr. Paris pointed out to me at Waipio were high in saline material but not sufficiently high at the time I sampled the soils to account for any growth failure. They were higher than where I found the Lahaina still growing well. The only reason I have to suspect high salt to have been associated with Lahaina failure at Waipio is that when those Lahaina experiments were put out at Waipio along about 1913, a very extensive set of experiments, they had a heavy rain, about 10 inches of rain in a few days, and the disease failed to appear in any of this planting. The soil would get a very extensive leaching in 10 inches of rain. Down in the Peninsula fields of the Oahu Sugar Company the saline accumulation is very high and the soils are very sticky, a character which is usually noted in a soil subjected to saline irrigation for a period of years. That is another point: in our pot experiments where we add large amounts of salts we probably reproduce the concentration of the salt but we do not reproduce the poor physical condition that we get from years of saline irrigation.

Agee: How about upper lands of the Oahu Sugar Company?

McGeorge: I have no theory at all about those fields. There is only one characteristic that I know of, that is, they are all low in phosphate and the poor growth of Lahaina there may have been due to deficiencies.

Agee: Phosphate starvation may have been the cause of their trouble.

McGeorge: Did Lahaina actually die there or was it just stunted?

Agee: I do not think that it actually died any place. In general the cane would be in great distress over the winter, and the second summer it would recuperate to some extent and would usually make four or five or six tons of sugar even in fields that had looked quite poor.

McGeorge: In one of Dr. Lyon's reports on some observations at Ewa he mentioned in his letter that the plant looked as though it were suffering from drought, even though there seemed to be plenty of moisture in the soil. That is a condition brought about by high concentration in the soil solution. The plant depends on the process of osmosis to obtain its salts and if the concentration in the soil solution is greater than that in the root cells you are going to have moisture coming out of the plant instead of going in. So that plant will wilt even though the soil is well saturated with water. Do you remember that case, Dr. Lyon?

Lyon: I recall the conditions.

McGeorge: Osmosis would be, I should think, the only way to explain that condition.

Lyon: In some of the swamps in Northern Minnesota you will find considerable deposits of iron in soil that is under the water. I am not positive but as I remember it, it is mostly ferric iron. Have you noted that condition in the swamps, Dr. Newcombe?

Newcombe: Yes, it is called bog iron.

McGeorge: At Waimanalo in Field 26 below the mill, which is one of those poorly drained sort of bluish soils, Mr. Chalmers, the manager, says that some-

times during very wet weather there will be standing water on that field and that water will be covered by a film of iron.

Lyon: That condition is very common in the forests on Maui. Regarding this iron in swamps: when I was in the Federated Malay States I had an opportunity to get into a swamp in which I noticed the same conditions. What would be the conditions that would permit that iron to remain as ferric iron?

McGeorge: I should think it would be a lack of sufficient conditions to hydrolize the iron and precipitate it, or possibly an acidity high enough to keep the iron in solution. I have seen the same thing in well waters coming from great depths. They will be perfectly clear, but on standing twelve to twenty-four hours will show a large precipitate of iron. I think it may be the lack of carbon dioxide at that depth.

Lyon: This is not carbonate; it is the oxide. It is always well down and it results through precipitation from a solution of ferrous iron, and you will find deposits of considerable depth in some of the bogs. There are certain bacteria that oxidize ferrous iron to ferric iron.

McGeorge: Soils contain deferrifying and ferrifying bacteria. At Olaa there is a great deal of ferrous iron in the soil. But in most of their best soils it is not permitted to accumulate as in some of the heavy soils at Waimanalo. Under those conditions it would be drained away, but as you get up in the Mountain View section there are some very poorly drained soils and at the same time the growth is very stunted. In most of the Olaa fields the water does not accumulate and I think the ferrous iron is leached away rapidly. Olaa conditions are very humid, under which conditions you do not get sufficient oxygen to form the ferric iron as has been found in drier island districts. It has not had an opportunity to reach the ferric form.

Lyon: In the soils beyond Kailua, Maui, we found that ferrous iron constituted 20 per cent by weight of the soluble materials. Those samples included only the upper 6 inches of soil. The soil is at all times saturated with water right up to the surface. You dig a hole and it fills right up with water. Is it not possible that we might use these ferrifying bacteria in some of our soils here? I think it is worth investigating. On Maui in the slow running streams draining down from these swamps there is an abundance of ferric iron but the soil solution as we found it is all charged with ferrous iron.

McGeorge: At Olaa we went to Mountain View section and one other section near Keeau Store and obtained samples of soil. They were too wet to run a test for ferric iron, but we ran a test for curiosity and it was negative. So then we put the samples in the oven over night and obtained a wonderful test for ferric iron. I assumed these would be good areas for an experiment, but after I got back to Honolulu and made a more careful test I found it was all ferrous iron and the soil was not sufficiently acid to have ferric iron present.

Lyon: It is very difficult to determine the amount of ferrous iron.

McGeorge: Yes, as soon as it hits the air it oxidizes. If the soils were inoculated where would the bacteria get their oxygen to do the work?

Lyon: They would have to work near the top, but they would go down as the oxidation of the ferrous iron proceeds and they would have to work at a

greater and greater depth. They work suspended in the solution and at different depths depending on the penetration of air into the solution. I suggested that we investigate these bacteria a number of years ago, but it has always been frowned upon as a dangerous proceeding because we might bring in some other organisms.

Agee: Why not bring it in a culture medium?

Lyon: They are very hard to culture. They have to be given very peculiar conditions.

Agee: Didn't you or Stewart conduct some work in which you attempted to study a soil which had been in cultivation for 20 years in comparison with an adjoining area which had never been cultivated at Ewa? What were the essential differences?

McGeorge: I ran the total carbons to see if the organic matter had been depleted and there was no change in the amount of organic matter in the cultivated soil. Stewart, I think, examined those samples for alkaline accumulations, that is black alkali, and I think he said that he found there was no tendency toward an alkalinity in any of the samples that he examined.

Agee: Do you remember any differences in organic matter?

McGeorge: We found no differences whatsoever. That was, I thought, explained by the work which you did. You weighed some cane roots and found 4 or 5 tons of roots to a 45-ton crop of cane.

Agee: I think most people completely overlook this when they talk about the necessity of applying organic manures. In a heavy root system they leave organic matter in the soil and organic nitrogen that was imported in chemical form.

Lyon: The roots are already well distributed and incorporated in the soil, too. In speaking of the upper fields of Oahu, in the past have you had rains heavy enough to leach these soils? There are probably lots of soils on this island that have never been leached.

McGeorge: I saw a figure the other day, I don't know how accurate it is, but it mentioned that a 15 months crop of cane required 216 inches a year. Now when you compare that with the rainfall in the cane growing districts there are few that are as heavy, so that you are bound to have these accumulations where your water requirement and evaporation greatly exceed the actual rainfall.

Muir: Where were those figures taken from?

McGeorge: Maxwell's Bulletin on Irrigation in Hawaii. We found one soil at Ewa which contained 50,000 parts per million total solids.

Agee: How much is sea water?

McGeorge: Thirty-five thousand. That is 15,000 more than sea water. And the H 109 cane did not seem to be injured by it. We find that this saline material increases during the summer and then decreases very materially during the winter season when the rains come on. You can get very definite measurements throughout the year on the changes in areas.

The Distribution of the Roots of Young D 1135 Plant Cane in the Soil

By H. Atherton Lee

In the studies of Lahaina disease, or growth failure, it has become evident that a knowledge of the root systems of normal cane is essential before conclusions can be drawn as to the relationship of root injuries to such growth failure. With this in view root-study boxes have been built which permit the washing away of the soil from the roots, and the roots when freed from the soil are held in position by a network of wires and so permit an examination of the underground system.

The first results obtained from these root-study boxes are apparently equally as interesting from an agricultural standpoint as they are in relation to root injuries. The following table shows the distribution of roots at different depths in the soil. Previous attempts at determining the distribution of roots have been by linear measurement which, because of the great numbers and branching character of the roots, could not be exact. For this reason in these studies the weight of roots was substituted for linear measurement and would seem to be a much better index of the presence of roots in a given area of soil.

TABLE I

Showing the Distribution of Roots of D 1135 Plant Cane 4½ to 5½ Months Old at Different Levels of the Soil [1]

	Topmost 8 Inches		8 to 16 Inches in Depth		16 to 22 Inches in Depth		22 to 30 Inches in Depth		Age of Plants
Plant No.	Weight Grams	Per cent	Weight Grams	Per cent	Weight Grams	Per cent	Weight Grams	Per cent	
1	71.4	58.5	30.6	25.0	6.9	5.6	13.1	10.7	145 Days
2	17.0	55.0	6.0	19.0	3.1	9.8	5.4	17.1	145 Days
3	133.7	68.8	25.8	13.2	15.3	7.3	19.5	10.0	161 Days
4	55.4	56.7	26.3	26.9	8.3	8.4	7.7	7.8	161 Days
5	96.8	64.1	31.9	21.1	10.6	7.0	11.5	7.6	168 Days
6	79.0	70.1	14.9	13.2	7.7	6.9	10.9	9.7	168 Days
Totals and averages....	453.3	63.9	135.5	19.1	51.9	7.3	68.1	9.6	

From the results shown in the foregoing table one observes that, averaging all plants, 63.9 per cent of all roots occurred in the top 8 inches of soil. In the next level, between 8 and 16 inches in depth, 19.1 per cent of the roots occurred,

[1] The root-study boxes in which these plants were grown were partially lowered into the soil to present natural conditions as nearly as possible. The cane was irrigated at no regular intervals but water was added from time to time to keep the soil moisture as nearly at optimum as possible. All plants received uniform applications of nitrate of soda but no phosphoric acid nor potash.

or a total for the top 16 inches of soil of 83 per cent. In the next level at the depth of 16 to 22 inches, 7.3 per cent of the total roots occurred or, taking the upper 22 inches as a whole, 90.3 per cent of the roots occurred in this upper 22 inches of soil.

The table shows a slightly higher percentage of roots in the bottom-most layer of 8 inches. This is because a few of the roots were beginning to reach the bottoms of the boxes and extend laterally.

The roots of the first two plants were examined when they were 145 days old; the next two plants were examined when 161 days old, and the last two when 168 days old. It might be argued that with age the percentage of roots at the lower levels would increase, but a careful examination of the figures shows no tendency in this direction and apparently, although the roots go more deeply with age, there is a corresponding increase of the surface roots at the same time.

In these studies two types of soil were used. Plants 1, 3 and 5 were grown in soil from the pathology plot, which has been notably free from any types of Lahaina disease, or growth failure. Plants 2, 4 and 6 were grown in soil from the upper part of Field 31 at Honokaa where D 1135 in small areas has suffered from soluble aluminum injury. The pathology plot soil is a heavy, loamy soil of a compact nature, while the Honokaa soil was much more loose and friable. The photograph produced shows the poor growth of the D 1135 in the soil from Honokaa with unusually active aluminum compounds, as compared with the growth in Makiki soil. A study of the roots in the Honokaa soil showed that in this five-month-old cane there was no abnormal rotting of roots; the principal difference was that the plants in the aluminum soil did not produce the quantities of roots which the plants were able to do in the Makiki soil. The differences in the amounts of roots in the two different soils are also shown in Table I. Plant No. 1 yielded 122 grams of roots, as compared to 31.5 grams of roots in Plant No. 2. Plant No. 3 yielded 194 grams of roots, as compared to 97.7 grams of roots for Plant No. 4. Plant No. 5 yielded 150 grams, as compared with 112 grams for Plant No. 6.

It is interesting to observe that the ratio of deep roots to surface roots was, however, practically the same in the two distinct types of soil used, the loose, friable Honokaa soil as compared to the heavier more compact Makiki soil. This is shown in the brief table following:

TABLE II

Showing the Similarity in the Distribution of the Roots of Five Months Old Plant D 1135 in Loose Honokaa Scil as Compared to More Compact Makiki Soil

Depth of soil	Roots of all plants averaged Percentage	Roots of plants in loose Honokaa soil Percentage	Roots of plants in more compact Makiki soil Percentage
Topmost 8 inches	63.9	62.6	64.6
Topmost 16 inches	83.0	82.1	83.5
Topmost 22 inches	90.3	90.0	90.5
Soil from 22 inches downward	9.7	10.0	9.5

Showing distribution of roots of five-months-old D 1135 plant cane in Makiki soil at the left, and a soil from Honokaa containing active aluminum compounds at the right. Roots in both series of soils are free from rots, but the photograph shows the small amount of roots found in the aluminum soil as contrasted with the Makiki soil. Distribution of roots in both types of soil shows more than 60 per cent of the roots in the topmost 8 inches of soil and 90 per cent of the roots in the topmost 22 inches of soil.

Such root studies as these are extremely slow, and expensive to carry into a large number of replications. The figures from the foregoing six plants, however, coincide to such a remarkable degree that apparently large numbers of plants are not necessary.

The relationship of such root distribution to problems of field preparation, cultivation, irrigation and fertilization seems equally as important as in the problems of root injury.

Studies planned by H. Atherton Lee.
Cane planted by D. M. Weller.
Root determinations by Clyde C. Barnum and D. M. Weller.

The Common Grasses in Hawaii in Relation to Mosaic or Yellow Stripe Disease

By H. Atherton Lee

A number of grasses which occur as weeds in cane fields show mosaic disease symptoms similar to those of mosaic disease in sugar cane. The following illustrations are presented here as a possible aid in the recognition of these grasses which serve as sources for infection to the cane.

Fig. 1 shows the grass most commonly affected with mosaic disease on unirrigated plantations. It is known locally as *kukai pua* grass, and since it is so widely known by this name we mention it here to aid quickly in recognition. It is usually a recumbent or semi-recumbent grass with hairy leaves and stems. The seeds are borne on a head which is distinctive in that the branches of the head do not expand outward but elongate in a closely held group; this is shown in the illustration. It is a species of the genus *Syntherisma*, *Syntherisma pruriens*. Other species of this genus are also commonly affected. This grass, *Syntherisma pruriens*, is not so common on irrigated plantations, although occasionally it is found. We have shown experimentally, here in Hawaii, that the mosaic disease of this grass is transmitted to cane.

Another commonly affected grass of the same genus is crab grass, *Syntherisma sanguinalis*. It is found commonly on unirrigated plantations on the windward slopes, although it does not occur as generally as the grass just mentioned, *Syntherisma pruriens*. Crab grass is also recumbent and hairy, but is not as large as *Syntherisma pruriens*, and the branches of the head on which the seeds are borne extend out laterally, often at an angle of 90 degrees from the stem. This enables easy distinction from *Syntherisma pruriens*, as shown in Fig. 2. Brandes, of the U. S. Department of Agriculture in Washington, showed experimentally that the mosaic disease of sugar cane was transmitted to this crab grass.

A third grass of this same genus is what we call creeping crab grass, *Syntherisma debilis*. It is a much smaller grass than either of the two just men-

Fig. 1. *Syntherisma pruriens*, Pig grass.

tioned, but with the head upon which seeds are borne, in general appearance similar to these other two. We have no illustration for this grass. A mosaic disease which we have never tested out to show its identity with sugar cane mosaic occurs upon this creeping crab grass. By analogy with the mosaic diseases of the other two species it seems very probable that it is the same disease.

Fig. 2. *Syntherisma sanguinalis*, Crab grass.

The corn aphis which transmits mosaic disease of sugar cane multiplies itself on all three of these grasses. We feel, in fact, that all the grasses of the genus *Syntherisma* should be regarded with suspicion as sources for infection of sugar cane. All three of these grasses commonly occur along roadsides and often along the edges of fields where the cane does not shade in. In fields, however, they are all commonly killed out when the cane shades in. Hitchcock considers all three of these species as introduced grasses.

On irrigated plantations the grass most commonly affected with mosaic disease is fox tail, *Chaetochloa verticillata*. Kunkel, in the *Planters' Record* for July, 1922, called attention to the mosaic disease of this grass as a possible source of infection for mosaic disease in cane. Since then we have experimentally transmitted the disease from fox tail to cane, proving the relationship of the disease in fox tail, as a source for the infection of cane in the field. Fox tail grass is shown in Fig. 3. Fox tail is a soft, succulent grass, usually erect, with a somewhat flattened stem, and the head upon which the seeds are borne is erect, cylindric, bristly, about 2½ inches long. This is the grass from which the bristles come which are frequently found sticking to a person's clothes. The corn aphis has been found breeding on this grass abundantly. Fox tail is an introduced grass in these Islands.

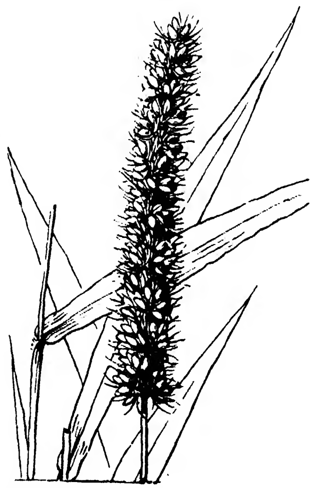


Fig. 3. *Chaetochloa verticillata*, Bristly Foxtail.

Goose grass, *Eleusine indica*, is a common weed on both irrigated and unirrigated plantations. It is not as frequently affected with mosaic disease as the species previously described, but occasionally shows symptoms of mosaic. Chardon, in Porto Rico, also mentions this grass as a source of infection to cane in that country. It is an erect grass, as contrasted with most of the *Syntherisma* species and grows in clumps rather than making a matted growth. The most easily recognized feature of this grass is the head, which consists of 3, 4, or 5 distended branches bearing closely packed seeds. The illustration in Fig. 4 enables one to recognize this grass much more readily than is possible from a written description. Hitchcock states that it is an introduced grass, originally found in India.

There are two grasses which occur commonly in wet places, such as rice paddies or in stilled water in irrigation systems. One of these is called paddy grass, and the other is known in the Eastern States of the mainland as the barnyard grass. Brandes has found that barnyard grass, *Echinochloa crusgalli*, can be infected with the mosaic disease of sugar cane. We have found the closely

Fig. 4. *Eleusine indica,* Goose grass.

related paddy grass, *Echinochloa colonum,* occasionally affected with mosaic disease in the fields, and by analogy with the other cases feel that it is probably identical with sugar cane mosaic. Both of the *Echinochloa* species occur in more or less erect clumps and are most easily distinguished by their branching heads as shown in Fig. 5.

Fig. 5. *Echinochloa colonum*, Paddy grass.

The corn aphis, *Aphis maidis*, feeds and multiplies itself upon all of these grasses which have been mentioned.

There are other grasses which contract mosaic disease which do not seem to be important as sources for infection of sugar cane. One of the forest grasses, *Isachne distichophylla*, has been observed on Kauai affected with mosaic disease, but it occurs so seldom in the vicinity of cane fields that as a source of infection for cane it does not seem important.

The True Seeds of Grasses Do Not Transmit Mosaic Disease

Although seed cuttings from plants affected with mosaic disease transmit it in 99 out of 100 cases in which they are planted, the true seeds of grasses have never been found to transmit the disease. Brandes, in Washington, tested out the true seed of mosaic-affected corn, sorghum, crab grass, and two other grasses, but in no case did the resulting seedlings show mosaic disease. Here in Hawaii, we have tested out the true seed from mosaic-affected Tunis grass, and Sudan grass, and in no case was mosaic disease inherited by the seedlings.

This has an important significance in plantation prevention of mosaic disease, for it means that if the vegetative parts of the grass are hoed out and killed, the seed which may be on such plants, even if it should germinate, would not transmit the disease. Elimination of sources of infection in grasses as weeds is thus made much easier.

Mosaic Disease in Weeds Which Are Not Grasses

The common weed honohono, *Commelina* species, is frequently seen with mosaic disease. Lupines and the sensitive plant found in fallowed fields also frequently show mosaic disease symptoms. The identity of the mosaic disease of

these non-grasses with the mosaic disease of sugar cane has never been established. However, should this mosaic of these non-grasses be identical, such weeds as honohono and the lupines would not seem to be important as sources for the disease in cane, since the corn aphis does not commonly feed and multiply upon these non-grasses.

The accumulating field and experimental evidence continues to point to the corn aphis as the principal insect, if not the only one, in transmitting mosaic disease in grasses in these Islands.

Grasses in Which Mosaic Disease Does Not Occur

Some of the most common grasses of these Islands, notably, Panicum grass, *Panicum barbinode;* Hilo grass, *Paspalum conjugatum;* red top, *Tricholaena rosea;* Bermuda grass (manienie), *Capriola dactylon;* and Buffalo grass, *Stenotaphum secondatum,* have never been observed affected with mosaic disease to date. The freedom of these common grasses from the disease considerably lessens the problem of the control of sources of infection for sugar cane.

Cultivated Grasses Which Serve as Sources of Infection

It is now generally known in these Islands that corn is a very dangerous source of infection for mosaic disease in sugar cane. The danger does not exist alone in the corn being commonly infected with mosaic but because the corn aphis multiplies itself so prolifically in corn. Mr. Muir has pointed out that the aphis can be wind borne for several miles, at least. A cornfield to the windward of susceptible cane will therefore allow countless disease-bearing aphis to float down on the cane.

A large proportion of the few serious outbreaks of mosaic or yellow stripe disease which have occurred in these Islands can be traced to the planting of corn along ditches or adjacent to cane fields. There seems to be little or no advantage to be gained from such corn plantings, since Professor Krauss, of the University of Hawaii, states that corn growing in these Islands is not a profitable crop.

The same is true of sorghum, since it is just as commonly affected by mosaic as corn, and the corn aphis multiplies itself fully as abundantly on sorghum as on corn. Many of the millets also contract mosaic disease, but fortunately they do not seem to be grown commonly in these Islands.

Tunis grass and Sudan grass, sometimes grown for forage, are also dangerous sources for infection of cane with mosaic disease; both grasses contract mosaic disease readily and on each the corn aphis multiplies abundantly.

There are two common grasses which we regard with suspicion although we have never observed mosaic disease in them. Johnson grass, *Holcus halepensis,* and Job's tears, *Coix lachryma-jobi,* are both plants upon which the corn aphis multiplies abundantly, but although we have seen leaves which showed suspicious symptoms of mosaic, none of the cases could be definitely called mosaic.

There are many forage grasses which do not commonly become affected with mosaic. Two such grasses upon which we have never observed mosaic disease in these Islands are elephant grass and Panicum grass.

Aids to Keeping Down Grasses in Cane Fields

Shading in by the cane, of course, eliminates many grasses as weeds. Anything to hasten the shading in of the cane thus contributes to lessening mosaic disease sources in weeds. Good sized seed cuttings with good eyes, not too hard, will shade in more quickly than small sized seed or seed with hard eyes. Early fertilization and irrigation contributes to keeping down mosaic.

Conversely, such practices as cutting back not only bring the cane back to a level where its leaves mingle with the weeds, but the period during which such grasses as weeds serve as sources for infection is doubled. Every time cane is ratooned the opportunities for spread of infection are greatly increased; much the same thing occurs when cane is cut back.

The practice of the laborers in planting corn along ditches is the worst thing possible and seems to be obsolete now in this country. The practice of planting sweet potatoes along ditch edges, firebreaks and roadside edges seems to be decidedly beneficial. Sweet potatoes do not show mosaic disease symptoms in these Islands and are not sources upon which the corn aphis can multiply abundantly; moreover they shade in disease-carrying weeds effectively.

Olaa Plantation has, of course, used weed poisons in their fields for years, and more recently the Onomea Sugar Company has mounted a small motor-driven paint-spray machine on a light truck and weeds along the edges of the fields are sprayed with weed poisons. Such practices aid in keeping down sources of infection in the grasses as weeds.

In our earlier studies of mosaic disease, planters told us that good agriculture would prevent mosaic disease; at the time we could not see the relationship between the two. It has gradually become apparent, however, that the prevention of grasses as weeds is extremely important, and good agriculture, as shown by prompt fertilization, irrigation, shading in of the cane, and other methods of weed control, contributes in a large way to keeping mosaic disease minimized in these Islands.

Summary

1. Crab grass, fox tail and several other grasses which occur as weeds in cane fields contract a mosaic disease which is identical with the mosaic disease of sugar cane. These grasses are also hosts upon which the insect which transmits mosaic disease, the corn aphis, multiplies itself abundantly. Such grasses are, therefore, important sources for infection of the cane with mosaic disease.

2. The true seeds of such grasses do not transmit the disease to resulting seedlings. Thus if the vegetative parts of these grasses are hoed out and dried up, such sources of mosaic infection in the weeds are eliminated, even if the seeds germinate and develop.

3. Not all grasses as weeds act as sources of infection for mosaic disease. In these Islands such common grasses as Hilo grass, Panicum grass, red top, Bermuda grass (manienie), and Buffalo grass have never been observed affected with mosaic disease.

4. Although several weeds which are not grasses show evidences of a mosaic disease, such weeds would not seem to be important sources for the in-

fection of cane, since the corn aphis which transmits mosaic does not commonly multiply on these non-grasses.

5. There are several cultivated crops which are grasses, and which contract the same mosaic disease as sugar cane, and upon which the corn aphis multiplies prolifically. Corn is, of course, well known as such a source for infection and sorghum and such forage grasses as Tunis grass and Sudan grass are equally as dangerous near cane fields.

6. Agricultural practices which aid the quick shading in of cane, and other methods of keeping down grasses as weeds, contribute considerably to lessening mosaic disease outbreaks.

We are indebted to the Bishop Museum for the illustrations of grasses, which were taken from *The Grasses of Hawaii,* by A. S. Hitchcock, and reproduced in this discussion. Figs. 2 and 4 originally came from Bulletin 772 of the U. S. Department of Agriculture. Figs. 3 and 5 originally came from Volume 22 of *Contributions of the National Herbarium.*

Lime for Upper, Acid Fields

KOLOA EXPERIMENT 20—1926 CROP

By J. A. VERRET

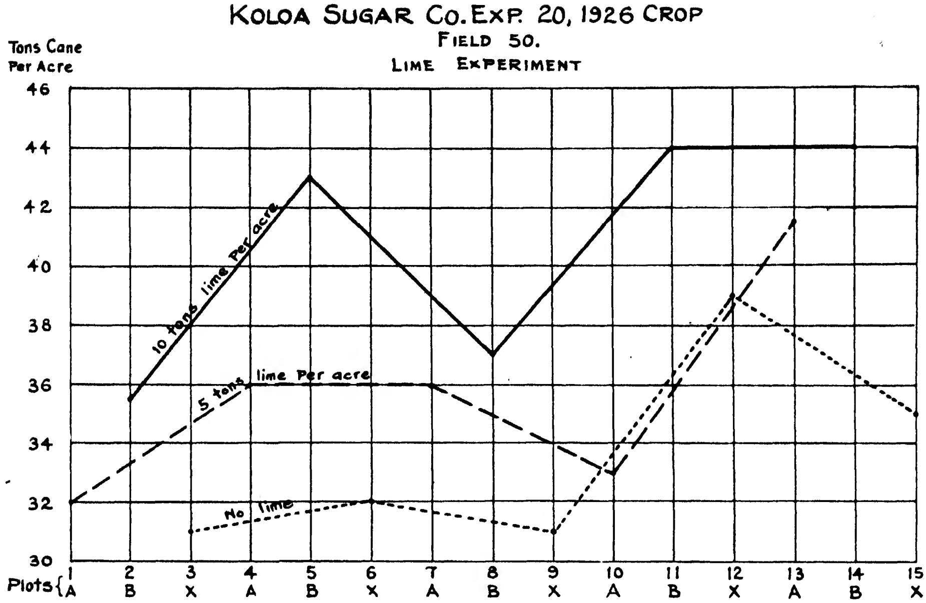
The experiment was located in Field 50, unirrigated, at an elevation of 500 feet. The cane was Yellow Tip planted in April, 1924, and harvested in March, 1926.

The experiment consisted of 15 plots. Five received no lime, 5 plots were limed at the rate of 5 tons of quicklime per acre and 5 plots at the rate of 10 tons per acre. All other fertilization was uniform to all plots and was done by the plantation. The soil in this field is decidedly acid, having a pH of 5.2.

The results are very definite and decidedly in favor of lime, as shown in the chart given herewith. In all cases the no-lime plots produced less cane than the adjoining limed plots. This is well shown in the chart. The results show that large amounts of lime are needed. The plots getting 10 tons of lime per acre without exception gave larger yields than the adjoining plots. The average gain was over 7 tons of cane per acre over the no-lime plots.

The limed plots had poorer juices than the no-lime plots, so the gains in cane weights are not reflected so strongly in the sugar yields. We feel that had this test been harvested later in the season, giving the cane more time to mature, better sugar yields would have been obtained.

Rat and borer damage was somewhat extensive in this area. It is to be expected that there was more damage in the ranker, more succulent cane in the limed plots, although this was not determined by actual count.



We hope to continue this test for a number of crops to determine the effect of lime on succeeding crops. Even larger gains may be looked for as the lime slowly reacts with the soil.

DETAILS OF EXPERIMENT

Koloa Sugar Company—Experiment 20, Field 50.
Lime Experiment—Comparing varying amounts of lime with no lime.
Cane—Yellow Tip; Plant; Unirrigated.
Planted April, 1924. Area, 1.467 acres.
Harvested March, 1926.

Fertilization

Plots	No. of Plots	Lime—Lbs. per Acre	
A	5	5 tons	10,000 lbs.
B	5	10 tons	20,000 lbs.
X	5	0	0

All other fertilization uniform to all plots.

PLOT YIELDS

Plots	T. C.	Acres	T. C. P. A.	Brix	Pol.	Pur.	Q. R.	T. S. P. A.
1A	3.205	.10	32.05	15.4	12.05	78.2	12.2	2.63
4A	3.677	.10	36.05	....	.....	....	....	2.95
7A	3.597	.10	35.97	....	.....	....	....	2.95
10A	3.330	.10	33.30	....	.....	....	....	2.73
13A	4.150	.10	41.50	....	.....	....	....	3.40
Total.......	17.959	.50	35.91	15.4	12.05	78.2	12.2	2.94
2B	3.555	.10	35.55	15.2	11.81	77.7	12.56	2.83
5B	4.295	.10	42.95	....	.....	....	.....	3.42
8B	3.695	.10	36.95	....	.....	....	.....	2.94
11B	4.435	.10	44.35	....	.....	....	.....	3.53
14B	4.417	.10	44.17	....	.....	....	.....	3.51
Total.......	20.398	.50	40.79	15.2	11.81	77.7	12.56	3.24

3X 3.122	.10	31.22	15.6	12.67	81.2	11.2	2.79
6X 3.230	.10	32.30	....	.....	....	....	2.89
9X 3.067	.10	30.67	....	.....	....	....	2.74
12X 3.887	.10	38.87	....	.....	....	....	3.47
15X 3.502	.075	35.02	....	.....	....	....	3.13
Total.......16.808	.475	33.61	15.6	12.67	81.2	11.2	3.00

SUMMARY

		Tons per Acre		
Treatment	No. of Plots	Cane	Q. R.	Sugar
5 tons lime........................	5	35.91	12.2	2.94
10 tons lime......................	5	40.79	12.56	3.24
No lime	5	33.61	11.2	3.00

Honokaa Sugar Company and Pacific Sugar Mill Fertilizer Experiment

By E. E. Naquin

Since 1916, due to economic conditions, potash and phosphoric acid were eliminated as fertilizing materials, and for the past ten years nitrate of soda has been applied almost exclusively on these two plantations. The manager was fully aware, however, that after potash and phosphoric acid had been exhausted these two elements would again become necessary to crop production.

Extensive field and observation tests were constantly carried on, so that we might anticipate this necessity.

Up to 1923 there was no indication of the lack of any other plant food than the nitrate of soda, which we were applying. Since then, however, several field tests have shown conclusively that the lack of potash and phosphoric acid is now being felt.

This was especially noticeable in Field 28, at Honokaa, where part of the cane was harvested without burning off and part after burning. The young cane which came up in the burned area showed such a marked improvement over the young cane in the non-burned area that we suspected the mineral constituent of the ashes to be the prime factor. Tests were then started in this field to show to what extent potash and phosphoric acid were necessary. (See Table I.)

The experiment just harvested showed a gain of 1.17 tons of sugar per acre directly traceable to potash; phosphoric acid alone gave .63 ton of sugar more, while potash and phosphate gave no greater yield than potash alone.

Mill ashes, at the rate of 4,000 pounds per acre, gave an increase of .61 ton of sugar per acre.

In these experiments 186 pounds of nitrogen, in the form of nitrate of soda, was also applied. The soil in this particular portion of the field is considered the best on the plantation and has always given us exceptionally high yields,

averaging close to 45 tons of cane per acre. This fact is probably responsible for the good showing made with potash and phosphoric acid in this instance. The high yields obtained from previous crops have undoubtedly drawn extensively on the reserve of these two elements and depleted these soils to such an extent that an immediate gain is noted when they are applied.

The plant food requirements of the different varieties vary considerably as shown by laboratory tests (see Table II) of the amount of phosphoric acid in juices of several of our standard varieties at Honokaa. As a rule D 1135 requires very much less phosphoric acid than does Yellow Caledonia and Yellow Tip.

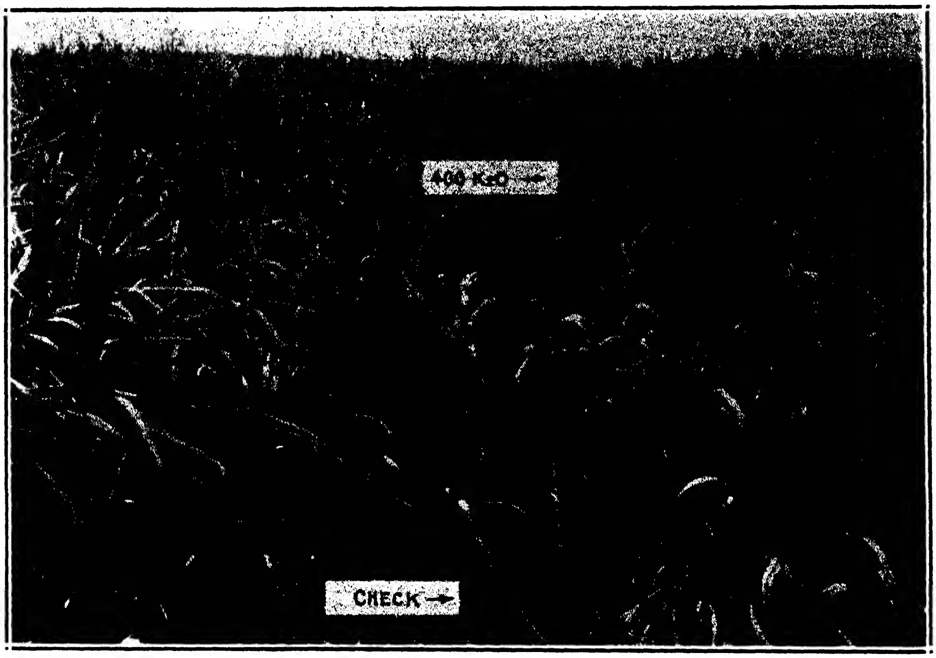


Fig. 1. Note heavy growth in background, where potash has been applied, as compared with the sparse growth in the foreground, which received no potash. The variety is D 1135.

Whether these same varieties react in a similar manner toward potash, silicate and the other mineral constituents of a normal growing plant is yet to be determined.

From our observations, since 1916 to date, it is quite evident that potash and phosphoric acid are becoming more and more important factors in crop production, and in the case of phosphate, at least the requirements of the different varieties vary considerably (see Table III) and that the symptoms, heretofore known as root rot or Lahaina disease, can be corrected by heavy applications of potash.

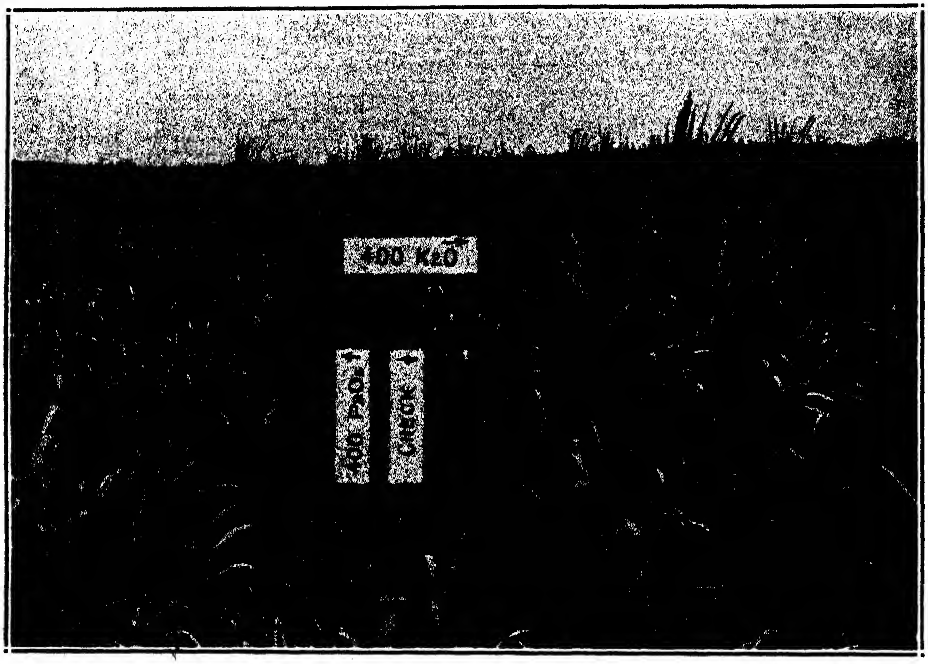


Fig. 2. The response to potash is shown by the higher cane in the background, as compared with the cane in the foreground receiving no potash. Phosphate in addition to nitrogen has but little effect, as may be seen by comparing the two plots in the foreground.

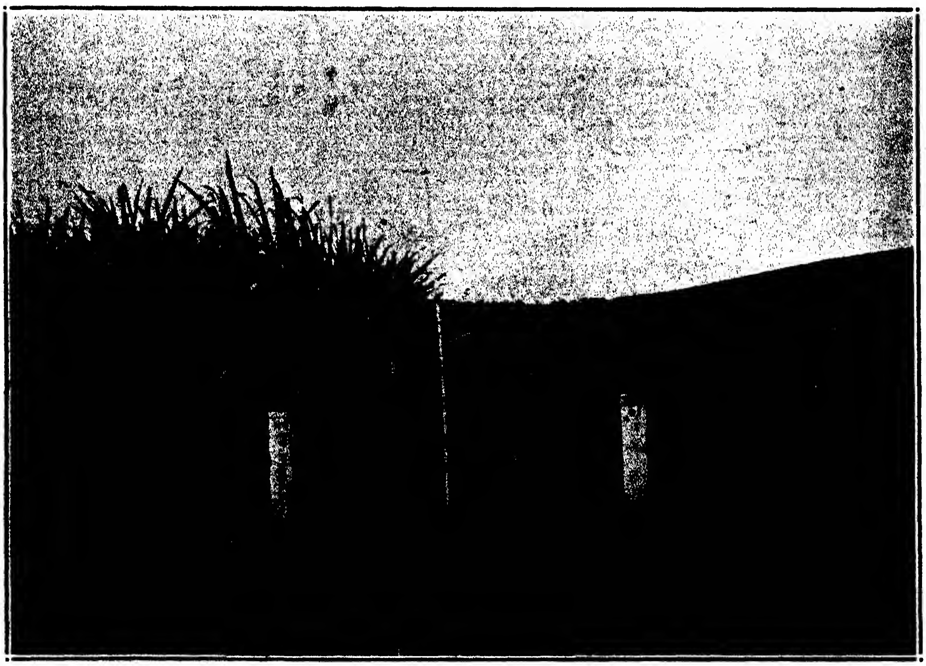


Fig. 3. The response to phosphoric acid in this field is clearly denoted in the heavy growth on the left as compared with that on the right. The variety is Uba.

TABLE I

FERTILIZATION EXPERIMENT

H. S. Co. 25, Field 28, D 1135, 2nd Ratoon, 1,000 ft. Elevation, Harvested July, 1925

No. of Plots	Fertilization N	P_2O_5	K_2O	Ashes	Juice Analysis (Crusher) Brix.	Pol.	Pur.	Q.R.	Tons per Acre Cane	Sugar	Gain or Loss Sugar
4	186	0	0	0	16.71	15.26	91.32	8.55	41.69	4.87	
2	186	200	0	0	16.94	15.61	92.15	8.31	45.14	5.50	+ .63
4	186	0	0	0	16.71	15.26	91.32	8.55	41.90	4.90	
2	186	0	200	0	16.94	15.61	92.15	8.31	50.44	6.07	+1.17
6	186	0	0	0	16.71	15.26	91.32	8.55	52.94	6.19	
5	186	200	200	0	16.94	15.61	92.15	8.31	61.17	7.36	+1.17
4	186	0	0	0	16.71	15.26	91.32	8.58	54.97	6.40	
2	186	0	0	4000	16.94	15.61	92.15	8.31	58.28	7.01	+ .61

TABLE II

Average Per cent Phosphoric Acid in First Mill Juice of Different Varieties of Cane

Varieties	No. of Analyses	Per cent P_2O_5
Yellow Caledonia	10	.0456
Yellow Tip	8	.0392
H 109	10	.0268
D 1135	10	.0225
Uba	5	.0148

TABLE III

Object: The effect of complete fertilizer on different varieties in root rot area.

Location: Honokaa Sugar Company, Field 31A, 900 feet elevation.

Crop: D 1135, Yellow Tip, Striped Tip, Yellow Caledonia, Badila and Honokaa No. 1. Planted May 21, 1923.

Plan: These varieties were planted in a diseased area and plots of each variety treated with complete fertilizer with alternate check plots. The treated plots received 400 lbs. P_2O_5 and 400 lbs. K_2O in one dose and all of the plots received 186 lbs. of Nitrogen in two equal doses.

Summary of results—Harvested July 9, 1925:

Nitrate of Soda Variety	Per cent P_2O_5 in Juices	Q.R.	Tons per Acre Cane	Sugar	Complete Fertilizer Variety	Per cent P_2O_5 in Juices	Q.R.	Tons per Acre Cane	Sugar	Gain or Loss Sugar
D 1135...	.023	9.62	55.83	5.80	D 1135...	.025	12.98	82.03	6.31	+ .51
Y. T.....	.025	10.06	38.78	3.85	Y. T......	.060	11.41	116.97	10.24	+6.39
S. T.....	.055	10.18	47.87	4.70	S. T......	.057	12.94	85.84	6.63	+1.93
Y. C.....	.050	9.09	51.47	5.66	Y. C......	.042	8.72	57.91	6.64	+ .98
Badila ..	.045	8.29	54.38	6.68	Badila ..	.032	9.38	52.37	5.58	—1.10
Honokaa 1	.040	9.75	72.72	7.45	Honokaa 1	.028	10.98	71.68	6.53	— .92
D 1135 ..	.023	9.62	44.09	4.58	D 1135...	.025	12.98	64.21	4.94	+ .36

We found from previous observations that Yellow Caledonia gave the earliest and most pronounced response to phosphate and potash. This early response must have hastened the growth and in consequence the ripening of this variety, which may account for the better juices in the treated plots. The response of D 1135,

Yellow Tip and Striped Tip was not so pronounced at the start and may account for the poorer juices in the treated plots of these varieties.

The yield of Badila and Honokaa No. 1 correspond with our previous obser--vations. These two varieties showed but slight response to complete fertilizer. The Badila showed early signs of distress in the non-treated plots, but it soon outgrew this condition. Honokaa No. 1 showed equally as good in the non-treated plots as in the treated plots at all stages of growth.

The percentage of phosphoric acid in the juices has a tendency to be higher in the treated plots.

Field Losses

By A. T. Spalding

The writer visited a number of plantations on the Hilo coast during the harvesting season of 1925 and noticed a good many fields where high stubbles were left on the ground. Few of us realize just how much cane can be left on the ground until you check up by cutting and weighing it. We hear about recovery and losses in the milling department and strenuous efforts are usually made by the mill hands to recover as much sugar as possible. It is easy to lose one per cent in the mill, but it is easier to lose double that in the field if one is not careful. Since getting in so many new Filipinos who have had little or no experience in cutting cane, the head and section overseers have had more or less worry getting clean fields. Where cane is burned the results are usually very good, but along the Hilo coast where burning is not practiced much there is considerable loss in the leaving of high stubbles.

The writer, at the beginning of the 1925 harvesting season, had an opportunity to find out losses incurred by the leaving of high stubbles. The figures submitted are no doubt above the average, but it is desired to bring out that the point of careless harvesting can soon amount to money. The man doing the cutting was a new Filipino who did not know how to use a knife. It was probably his first attempt at cutting cane and after he was shown the proper method he made a good showing. However, if we should even consider the half of this loss it would amount to a great deal in the course of a crop. The lower part of the stalk, as we all know, is rich in sucrose and juice analysis was not taken. The following figures are submitted:

Length of Row	Gross Lbs.	Tare Lbs.	Net Weight	Cane per Acre
102 feet	38	4	34	2727 lbs. (5½ ft. rows)

Nematode Parasitic Upon Termites

The following translation of a paper by C. Lespés[1], published sixty-nine years ago[2], is of interest to us on account of the damage done by white ants, or *Termites,* to property in our islands.

In the course of my observations on the *Termites,* I have twice seen numerous nests, which appeared to be in a state of great prosperity, entirely destroyed in a few days. These two societies were established with me in large glass-vessels, but the earth of the nests was too moist; in this earth I then saw an immense number of little white worms swarming, and by examining them carefully and dissecting the *Termites* of these societies, I have been enabled to ascertain the history of the parasite. In its characters this Nematoid worm closely approaches *Leptodera* of Dujardin, but it must form a distinct generic group, as several of its characters differ from those of *Leptodera*—its mouth is armed with three tubercles, its neck is short and thick, and lastly it is oviparous, whilst *Leptodera* is viviparous. The characters of the generative armature of the male are identical, but the aliform expansions so remarkable in M. Dujardin's worm are wanting in mine.

(Here follows a description of the nematodes.)

The adult males and females of this species are common in the earth of the two nests. They presented the remarkable property of being capable of being recalled to life after complete desiccation for more than a month. The males are rather less abundant than the females.

In these little creatures we may perfectly distinguish the digestive tube, which commences with a muscular pharynx, followed by an intestine which is straight in the male, and twisted into a spiral in the female. The former presents a slight tubercle a little above the tail; in the corresponding part we see the two spicules of 0.05 mil. in length, and the sheath of 0.02 mil. which is placed below. The generative orifice of the female is placed about the middle of its length; by transmitting light we see a great number of eggs filling the body.

With these animals I found an immense number of free eggs in different stages of development. Those furthest advanced contained an extremely mobile embryo. Some of these escaped, but there was still a gap between the young individuals and the adult or nearly adult forms. To supply this it is sufficient to dissect a *Termite* of the infested nest, when we find in the abdomen, around the intestine, but never in its interior, some Nematoid worms, very short and slender when compared with the adults; they are in different stages of development, but the generative organs are always wanting. I found from one to six of them, but only in individuals of a certain size (workers, soldiers, nymphs). All my observations were made at the beginning of May, and in the second nest I verified them in June. The infested insects soon languish and at last die; if they are then examined. the developed Nematoid worms are seen issuing from their bodies, which are becoming putrefied.

From these facts I think that all naturalists will admit with me, that the parasite of which I have just given the history, acquires its generative organs and propagates in moist earth; that the young penetrate into the bodies of the *Termites*, become developed there, finally destroy their victim, and then escape to complete their growth.

The study of the probably numerous worms which have been united under the name of *Filariae* of Insects, was commenced by the remarkable work of Von Siebold upon *Mermis albicans.* The facts which I have just described, seem to be a copy of those made known by that learned naturalist.

In the digestive table of the *Termites,* I have found a considerable number of parasites.

F. M.

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[1] Ann. Sci. Nat., V., Zool., p. 335.

[2] Ann. Mag. Nat. Hist. Second Series, Vol. XIX, 1857, p. 388.

U. D. 92

One of the Uba hybrids which offers promise on account of having a fair sized stick, fair sugar content, heavy stooling properties and drought resistance. The clumps shown here are plant cane from seed pieces spaced five feet apart.

So-called Fillers in Mixed Fertilizers

By C. G. Owen

In order to help clarify a situation which exists and proves a great annoyance to fertilizer manufacturers and is the cause of misunderstandings on the part of consumers of commercial fertilizers, the following facts are put forth and should be more generally known.

The term filler is assumed to be any material added to a mixed fertilizer, which is not required to satisfy the analysis called for. It will be seen immediately that any composition which calls for a mixture of raw materials to satisfy a required analysis and which weighs less than 2,000 lbs. must have weight added to secure the ton unit generally used in fertilizer calculations.

Most times the supposed amount of filler used is more apparent than real because the raw materials in the composition of a complete commercial fertilizer are of great variation, for instance—

Superphosphate analyzes from 16 per cent P_2O_5 to 20 per cent P_2O_5, according to the grade of phosphate rock available to the manufacturer. Other ingredients range as follows:

Bonemeal, from 18 per cent P_2O_5 to 26 per cent P_2O_5, 2½ per cent nitrogen to 4 per cent nitrogen.

Potash materials, such as sulphate of potash, muriate of potash, double manure salts, kainite, potash nitrate—from 14 per cent K_2O to 58 per cent K_2O.

Nitrate of soda from 14½ per cent nitrogen to 16 per cent nitrogen.

Sulphate of ammonia from 20 per cent nitrogen to 21 per cent nitrogen.

Dried blood and other organics from 9 per cent nitrogen to 14 per cent nitrogen.

On account of these wide variations it will be seen that a considerable choice can be had in making up any required formula. On this account formulas that call for raw materials which by weight total 1,925 lbs. or over should be considered fertilizers without fillers. The difference between 1,925 lbs. and 2,000 lbs. is a necessary allowance to give a choice of grades in the raw materials mentioned in accord with market conditions. Any insistence on a definite composition of raw materials results in a higher cost and is therefore impractical.

The average complete fertilizer is composed of about seven different chemicals or raw materials and if an allowance of only 10 lbs. for each ingredient is figured it will be seen a necessary leeway of 70 lbs. results.

Again, any required formula cannot be figured safely to the second decimal point, as owing to the different specific gravities of the materials involved no mixture would remain accurate upon the slightest agitation of transportation and handling; consequently the manufacturer must figure in excess to the extent of about two-tenths of 1 per cent to avoid the possibilities of claims for shortage. This results in an additional leeway of 40 lbs. per ton, the same being 2 per cent of 2,000 lbs.

For the sake of argument let us assume that no leeways are calculated, and to satisfy a given formula about 1,900 lbs. of materials to the ton are required, the question then is what shall compose the extra 100 lbs. to make up the full ton? The manufacturer has a choice first of choosing a lower grade of any of the materials making up the composition or can use carbonate of lime or sulphate of lime, which are considered of agricultural value.

A paradox in regard to this subject exists, for if one purchases, we will say, nitrate of soda which contains 15.5 per cent nitrogen, it is considered without filler, although as a matter of fact the nitrogen is only what is required and there is really 84½ per cent filler, which obviously cannot be avoided; yet if a customer ordered a fertilizer containing 15½ per cent nitrogen from sulphate of ammonia, which would call for but 1,500 lbs. of this chemical, then 500 lbs. of some other ingredient would have to be used, and it would be considered a fertilizer with a filler. The question is, why should this be and how can further endless discussion on this subject be avoided?

As time goes on and the chemical industry finds methods of producing at comparative costs still higher concentrated goods the more we will hear of the so-called filler. In fact, if the concentration reaches too high a point it will probably be necessary to dilute such chemicals, as their use in the concentrated form in large quantities might prove detrimental to plant culture, or they may have to be diluted in order to get better distribution on the field.

Perhaps this question can never be settled, but in order to secure a closer understanding and cooperation between the manufacturer and his clients we believe a line should be drawn somewhere and we suggest 1,925 lbs. as the basis for discussion.

An Authentic Bud Variation in Potato*

As recently as 1918 so experienced a plant breeder as A. Sutton expressed the view that "there is no ground for believing nature ever has given rise to any new and distinct variety of potato by bud-variation." The point at issue is of first-rate importance, both scientifically and from the practical point of view, and it is therefore very interesting to have R. N. Salaman's confirmation, as the result of extensive breeding experiments, of Mr. McKelvie's original view that he had found an authentic bud sport turning up in the case of the Arran Victory potato. Thus sponsored, this bud sport, or somatic mutation, deserves the most serious consideration. Actually a series of such sports has been under observation, the obvious point attracting attention to them being the suppression of patches of the purple coloration in the skin, leading ultimately to a form with white tubers with occasional patches of color, or, in the extreme form, tubers with a pure white skin. Most of the forms thus arising produce plants with vegetative form and foliage

* From *Nature*, October 17, 1925, No. 2920, Vol. 116.

indistinguishable from Arran Victory; but one remarkable mutant has definitely a different growth form and different shaped leaflets, a point noticed by McKelvie and completely confirmed by Salaman. This same mutant also shows the tuber form altering in a large majority of its produce from the typical round tuber of Arran Victory towards a typical "kidney." Mr. Salaman has carried out crossing experiments with these bud mutations, with the result that the loss of pigment in the tuber appears to be accompanied *pari passu* with a reduction in the number of ovules capable of giving rise to colored tubers. Thus it appears that a change arising in a vegetative shoot and propagated in the first place vegetatively, a change presumably in the genes controlling color formation in the tuber but, in one mutant form at least, associated with other far-reaching changes in the constitution of the plant, has been associated with changes in the genetic constitution of the germ cells. Mr. Salaman describes his breeding experiments in the *Journal of Genetics* (Vol. 15, No. 3, July, 1925), his final conclusion being that "A somatic mutation which is characterized by the loss of a specific character such as pigmentation of the tuber skin, may evince this loss in other directions both in its own body and, through its germ cells, in its offspring."

[J. A. V.]

The Influence of the Cattle on the Climate of Waimea and Kawaihae, Hawaii

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From the *Sandwich Islands' Monthly Magazine*, Issue of February, 1856

That clearing the land ameliorates the climate, is an established fact in the science of Meteorology, but in the instance now under consideration, there are circumstances which appear to render the case peculiarly interesting. In the first place, all the phenomena concerned are within comparatively confined limits. One can stand on a point of rock and include at a glance the whole theatre of operations. The time in which the change of climate has been effected is short, and within the memory of men now living in the district, and the change itself is so palpable as to have rendered an old established custom of the natives no longer necessary. In the second place, the locality being on an island within the range of the steady trade winds, it is out of the reach of the numerous complicating and disturbing causes which effect atmospheric phenomena in regions differently circumstanced. And finally the chain of causes and effects produced is more extended than appears to be the case in most other instances.

The Waimea plains may be described as an elevated plateau, some ten miles long, four or five miles wide, and perhaps four thousand feet above the level of the sea. At each end they are bounded by a steep slope towards the sea. On one side of the plain is Mauna Kea, and on the other the Kohala range of hills. The northeast trade wind blows almost directly along this plain, and being drawn, as it were, between two mountain ranges, is generally pretty strong. Kawaihae is situated on the beach at the bottom of the slope on the lee or western side of

the elevated plateau. The trade wind does not usually blow at Kawaihae; it seems, after sweeping the plains, to continue a straight course without descending the slope, leaving that place under the influence of the regular land and sea breezes. On travelling in the day time from the beach up the hill towards Waimea, we generally start with the sea breeze behind us, which continues until we get to about the brow of the rise—we then arrive at a region of calm—of only a few hundred yards in extent, however—for almost immediately we are met by the cold trade wind in our faces. If the journey be made at night, we usually start with a gentle air from the land, which gradually dies away as we ascend, until reaching the brow as before, the same cold breeze salutes us, and bitter cold it often feels, on so suddenly leaving the hot region below. Two marks might be set up only a few hundred yards from each other, which would probably for three hundred days in the year, include the debatable ground between the limits of this cold trade wind, and the warmer land and sea breezes below. There are, however, disturbing causes, one is the southerly wind which at certain seasons prevails over all this part of the ocean, and when prevalent annihilates for the time all the winds just alluded to. The other is the wind which we have more particularly to consider in relation to our present subject.

This is the wind called *Mumuku,* the tremendous gusts which occasionally sweep down the slope towards Kawaihae, whirling clouds of dust out to sea, blowing sometimes all day and night, when, of course, the usual land and sea breezes are destroyed. It is nearly coincident in direction with the trade wind, and also with the land breezes, that is to say the three winds, although independent of each other, *all blow in the same direction.* The trade wind and the southerly wind, are independent of local circumstances—but the land and sea breezes at Kawaihae and these *mumukus* are peculiarly local winds, and are effected by local circumstances. The following extract from Brande's Encyclopedia is a succinct and easily intelligible account of the cause of land and sea breezes:

> During the day the surface of the land becomes more heated than that of the adjacent ocean, and the air over the land, in consequence of its greater rarefaction, is displaced by the denser air rushing from the sea. Hence a current, or *sea breeze,* beginning at the same hour in the morning, and continuing till the sun is near setting, will flow from the water towards the land. At night the water remains warm, while the surface of the land cools rapidly; and hence the current sets from the land towards the water, and forms the *land breeze.*

The two main causes which we find adduced to account for winds and storms in general are, the difference of the temperature of the atmosphere in two regions, and the sudden condensation of vapor, by which the equilibrium of the atmosphere is destroyed—and the wind is the rush of air to restore it. It follows, therefore, that the greater this difference of temperature, or the greater the amount of vapor to be condensed, so much more violent will be the resulting winds and storms.

In the case before us then it is not difficult to perceive a very fertile cause of the *Mumukus,* for we have a cold moist trade wind approaching a current of air at a comparatively high temperature, for the latter although originally a sea breeze and tolerably cool, before it meets the trades, has passed over four or five miles of black lava rock heated perhaps by ~~an~~ afternoon tropical sun. Any cause disturbing the equilibrium of these currents would be likely to produce very

violent motion. Let us suppose one case—a strong trade wind sweeps over the plains heavily loaded with moisture, so much so that a portion falls in rain over the heated lava rocks on the slope towards Kawaihae—this suddenly cools them—the circumstances which were producing the sea breeze are reversed, the causes which produce the land breeze are in operation—the direction of the current of air is suddenly altered, whilst a steady gale is at hand, to back up the local rush of the cooled atmosphere to the now warmer regions at sea.

Fortunately these hurricanes are now not nearly so violent or frequent as they used to be some twenty-five or thirty years ago. The old residents all affirm this, and they state that formerly the *Mumukus* were so common and violent, that the natives made a regular practice of lashing their canoes which were hauled upon the shore to a rock, stake or tree, to prevent them being blown off the land into the sea. This practice is now given up, being no longer necessary.

But what have the cattle on Waimea plains to do with these hurricanes?

It is in the memory of many foreigners now living there, when the whole of these plains were covered with a thick wood, to the very edge of the slope. Where now hardly a tree is to be seen for miles, we were informed by an old resident, that twenty-five years ago he lost himself with his team in the woods. He also stated that at that time there was far more rain at Waimea than there is now, which indeed might be readily inferred, as clearing the land of trees invariably lessens the quantity of rain. This clearing of the land has been almost entirely effected by the cattle. The few head brought by Vancouver in 1793 increased so rapidly, that early in the present century thousands of them were killed for their hides. At this moment they swarm in the thick jungle that covers the windward or eastern slope towards Hamakua. They are now gradually destroying this, and thousands of old dead trees, both standing upright and lying prostrate, form the present boundary of these woods, and exhibit the mode in which the destruction is effected; for whilst the old trees die of age, no young ones are seen taking their places, as during the last thirty or forty years, the cattle have eaten or trodden them down.

At the present time the vapors and rain which are brought across the plain by the trade winds are generally dissipated between Waimea village and Lihue, which latter place is something under a mile nearer the brow of the hill, and it is quite usual to notice that at Lihue the weather is fine and the sun shining, whilst at Waimea it is wet, raw and misty. This spot where the vapors now commonly terminate, is three or four miles from the debatable ground between the two winds before alluded to.

But when some twenty-five or thirty years ago, woods extended over the whole plain and to the very edge of it, close on to this debateable ground—and when rain was in consequence more frequent over this district, the vapors and cold moist atmosphere, instead of being dissipated near Waimea village, would necessarily have more frequently extended to the debatable ground; so that the peculiar conditions which as we have seen are the main causes of winds, were then greatly intensified and probably at the highest pitch, and instead of a moderate *Mumuku* now and then as at present, these tremendous gusts must have been an almost every day occurrence. The few miles of open warmed ground and sun-

shine now tempers the trade wind before meeting the sea breeze, but when covered with foliage it would have had a contrary effect, by attracting the vapors.

To put the case in a few words—there is usually a much smaller difference now, in the temperature and in the moisture of the conflicting currents of air which are concerned in the formation of these wind storms, than there was before the cattle destroyed the woods; and they are now less frequent and violent accordingly.

When the natives of different districts of these islands tell us that their climate has altered since the white men came amongst them, we are apt to treat their statements as fanciful, and to imagine that there can be no more connection between the two, than there is in the celebrated instance of the erection of Tenderden steeple and the formation of Goodwin sands. The old natives assert that there is *more* rain in Honolulu *now*, than there was before the white men came. This is the opposite effect to the one just treated of and is singularly corroborative of the correctness of the principle adduced; as here the old residents tell us of the time when there was hardly a tree in the lower parts of Nuuanu valley—the white people came and planted them—and now—Honolulu and a large portion of the valley presents to the view, a pretty liberal sprinkling of foliage.

The simple observation of facts by the ignorant and the savage, is often more correct than that of cultivated people, and it would be well to carefully examine all their statements, and ascertain if there is not a reason for them, however absurd they may appear. For, as in the present instance, what proposition seems more unlikely, than that the landing of a few head of cattle at Kawaihae, by Vancouver in 1793, should diminish the violence and frequency of the hurricanes at that place in 1856, and yet a little examination shows it to be in a high degree probable not only that there is a connection, but that it is close and easily traceable. Indeed, we seem to have at Waimea and Kawaihae, a remarkably compact example, a cabinet specimen as it were, of the mutual action and reaction on each other, of earth, air, sea, men, animals and plants.

[L. W. B.]

Explosions in Air Compressors and Receivers*

Explosions in air compressors and receivers occur with sufficient frequency to demand careful attention. The majority of such explosions are undoubtedly due, either directly or indirectly, to the lubricating oil used in the air cylinders. Poor working conditions of the compressor, such as leaking valves, hot and dirty inlet air, insufficient cooling water, carbon deposit in cylinder or connections, and high speeds of poorly designed compressors, all assist in producing dangerously high temperatures of the compressed air. These high temperatures are sufficient to ignite the volatile constituents of the lubricating oil, and produce violent explosions; therefore:

* Taken from *California Safety News*, Vol. 9, No. 4, December, 1925.

(a) Keep the temperature of the compressed air during compression as low as possible.

(b) Keep the piston and valves tight, and in good working condition.

(c) Take the inlet air from as cool and clean a location as practicable.

(d) Use plenty of cold water, from a source which is not liable to fail, and have it visible at discharge from cylinders or coolers.

(e) Do not use kerosene or other volatile substances in the cylinder, tanks or any connections.

(f) Use mechanical or sight feed oilers for the compressor cylinder.

(g) Use the least amount practicable of the best air cylinder oil. Air cylinders require much less oil than steam cylinders.

(h) Never use steam cylinder oil in an air cylinder.

(i) Keep the cylinder, tanks and connections as free from carbon, accumulated oil and deposits as practicable.

(j) A good cylinder oil is one which lubricates well, leaves little or no deposit, is the least volatile at high temperature, and has a high flash point. Observance of the foregoing suggestions will prevent many accidents.

The less a man's time is worth the less willing he usually is to take the necessary precautions for safety.

[W. E. S.]

Pahala Blight and a Comparison with Other Forms of Sugar Cane Chlorosis

By W. T. McGeorge

For some twenty years or more cane grown in many fields of the Hawaiian Agricultural Company in the Kau district on the island of Hawaii has been seriously attacked by a chlorotic disease. Owing to the locality, Pahala, it has from the very beginning been termed Pahala blight, but is also known as the leaf-splitting disease. This latter term was probably derived from the fact that the disease first makes its appearance in the form of yellow stripes along the smaller vascular bundles of the leaves and along which the leaves split during strong winds. The term blight was probably derived from the fact that the fungus or fungi associated with the wilted condition of the plant causes a wilting in the most seriously affected plants. Cobb identified *Mycosphaerella striatiformans* as being active upon affected leaves.

Description of Disease

The following description is given by Cobb in Bulletin 5, Pathological Series, of this Station:

The early stages of the onset are to be observed in cane that is only a few weeks old, but the symptoms are more easily seen in cane that is several months old. It may be observed in cane upwards of a year old, but to plants of that age it does not do so much harm as to younger ones. The earliest symptom is a slight alteration in the coloring of the leaves, this alteration being observed first on the outer leaves, and toward their tips rather than lower down. The alteration in color takes the form of stripes, due to the loss of green color in the tissue carrying the small vascular bundles. On a line half way between the larger fibres or the vascular bundles of the leaves the green color fades and is succeeded by a whitish yellow. At first these pale streaks are narrower than the green streaks that separate them, but as the disease progresses the whitish streaks become wider and the green ones narrower, until at last the greater portion of the leaf is light colored. . . .

The striped appearance begins near the tips of the leaves and occurs on the outer leaves first. As time goes on the inner leaves become affected and the stripes progress downward.

During the striping stage the leaves remain succulent and retain their full width. Leaves in the final stages of the striping process are very conspicuous objects.

When the striping has so far proceeded as to destroy most of the green color of the leaves the lighter portions of the leaves begin to shrivel and assume a dry, whitish appearance such as is characteristic of light-colored dead grass leaves. On examining one of the dry stripes attentively it will be seen to be more or less filled with minute black specks barely visible to the unaided eye. These are small subspherical growths just below the surface of the leaf and the microscope shows that each is a hollow sphere filled with spores.

The following description by Lyon is also of interest:

Pahala blight is in effect a bleaching and destruction of the chlorophyll. As a rule the chlorophyllous tissues around the minor vascular bundles only are affected, the green tissues around the major bundles becoming involved only at a late stage in the disease. As a result a newly affected leaf displays a very definite striped appearance, green stripes alternating with yellowish green or white stripes.

In the affected tissues the chloroplasts first lose their definite outline, then run together in a pale yellowish green mass and finally lose all semblance of green color.

The first indication of an attack of Pahala blight noticeable in a cane leaf is a paling or bleaching of the green tissue at the proximal ends of the minor vascular bundles. The bleaching proceeds upward and outward through the blades of the leaf along these bundles, producing light stripes of uniform width which may eventually extend to the very margin of the leaf. The progress of the disease may be slow or very rapid. In some cases the paling of the tissue in the stripe is very gradual and may not proceed beyond a light greenish yellow; in other cases the paling is very rapid, the tissues being quickly bleached to a sickly yellowish white.

A cane shoot may show a mild case of Pahala blight, continue in the same condition for months and eventually recover. Then, again, the disease may reach an acute stage only a short time after the first symptoms have become apparent, but the shoot usually lingers on for months before it finally succumbs. If the chloroplasts are seriously injured the tissues never recover, but die and are soon invaded by various saprophytic fungi. When canes become seriously affected by the blight they stop growing and remain practically dormant until the blight factor ceases to operate, then they do not recover by rehabilitating the old tissue but produce new and healthy tissue. Consequently they show a very abrupt transition from diseased to healthy tissue. One leaf may be very badly marked by the blight and the very next younger leaf show no sign of the blight at all. Then, again,

the upper portion of the leaf may be distinctly blighted while the basal portion is quite free from blight. In such a case the basal portion has been produced after the blight factor ceased to operate.

The appearance of blighted fields is well illustrated in Fig. 1.

Cobb concluded that the fungus *Mycosphaerella striatiformans* was directly responsible for the disease. Later, Lyon showed that this fungus was saprophytic rather than parasitic and that it only entered the tissues of the leaves after these tissues had been injured by the blight. On this basis and the fact that there were definitely defined areas at Pahala which are always free of blight, Lyon suggested that the blight was induced by a "factor or factors resident in the soil."

Following this a number of field experiments were conducted to determine the relative resistance of varieties and to search for a method for its control.

Resistant Varieties: Observation Test A (1921 crop, Williams) compared Rose Bamboo, Striped Mexican, Caledonia Ribbon, H 72, H 227, H 291, Yellow Bamboo and D 1135. All these varieties became blighted, but D 1135 made a notable recovery and H 72 a partial recovery. D 1135 still continues to be the most resistant variety.

Field Experiments: Observation Test B (1921 crop, Lyon and Williams) compared mud press, stable manure, magnesium sulphate and iron (ferrous) sulphate. Of these treatments stable manure in very heavy applications gave excellent response. There was a slight temporary betterment in leaf color in the iron sulphate plots.

Similar treatments were obtained in Observation Test C. In this case an excellent improvement was obtained by pouring the iron sulphate solution upon the soil around the roots. This greening of the leaves was only temporary, however, and soon disappeared.

In Observation Test D (1921 crop, Lyon, Williams and Alexander) an exhaustive set of field experiments was installed to determine if volcanic gases arising from the subsoil were associated with the disease. For this experiment one-foot excavations were made in a blighted field and a layer of charcoal placed at the one-foot depth. This experiment also included heavy manure applications and a transfer of soil from the Mudflow field to an excavated plot. The Mudflow field has never in the history of the plantation shown any blight. Only the heavy manure application and the transported soil showed normal growth. Cane on the charcoal plot was a total failure.

Observation Tests E and F (1921 crop, Lyon and Doty) were then installed in order to test the effect of spraying a 4 per cent solution of iron sulphate upon the chlorotic leaves. The result of this experiment was that the leaves were badly burned by the spray and there was no sign of a recovery.

Heavy fertilizer applications were tried in Experiment 3A (1922 crop). These included ammonium sulphate, 1,250 pounds per acre; acid phosphate, 500, 1,000 and 1,500 pounds per acre; sulphate of potash, 800, 1,600 and 2,500 pounds per acre, and muriate of potash, 500 and 1,000 pounds per acre. Considerable response to sulphate of ammonia was obtained and some response to sulphate of potash.

A number of green manuring experiments, using eight different legumes, were tried, but with questionable results.

The above is a review of the work which had been done on this problem previous to January, 1924, at which time a request was made for further investigation. The most significant points, that is, those which seem to stand out in these experiments are: (1) the temporary response to iron sulphate when applied in solution to the soil about the roots, (2) the burning of the leaves when this salt is used as a spray, and (3) slight response to sulphates of ammonia and potash, both of which, especially the former, are residually acid fertilizers.

Plan of Investigation

In planning a chemical investigation of this problem it was necessary to recognize a number of different phases which were apparently of more or less equal importance. Among these may be mentioned the poor root development and scanty root system of blighted plants. On digging up such plants the stalk was usually still feeding through the seed piece (plants 10-12 months old), which was still solid and showing little or no signs of decay. The stalk itself had few roots capable of supplying plant food. In direct contrast neighboring plants not attacked by the blight had excellent root systems and the stalks were no longer dependent upon the seed piece for their nutrition. The seed piece on such plants was almost completely decayed and the plant with its own root system was "shifting" for itself. This well developed root system extended 2-3 feet into the subsoil.

The appearance of the leaves suggested chlorosis probably resulting from some form of physiological or nutritional disturbance. On the other hand, in the badly affected plants, that is, the blighted ones, the leaves were severely etiolated, curled, were damping off and gave every evidence of a severe fungus attack which in many cases finally developed into top rot and the death of the plant. Plants showing only the typical chlorosis rarely die and some are even little retarded in growth. In fact, chlorotic and non-chlorotic shoots are often to be noted in the same stool. On this basis it appeared that the chlorosis might be only one of several factors involved as causal agents in this blight. Lyon has reported the same type of chlorosis, namely, the leaf striping, at Waialua Agricultural Company. Cobb reported also seeing it on other plantations. Carpenter reported it at Wailuku Sugar Company. The writer has observed it at Waialua, Ewa, Oahu, Hawaiian Commercial and Sugar Company, Honolulu and Honokaa plantations and also at the Makiki Plots of the Experiment Station. On the other hand, to my knowledge Hawaiian Agricultural Company is the only plantation on which this chlorosis is followed by a blighting of the plant.

Our work was therefore divided into soil studies and a biochemical study of the plant. An additional study was made of soils and plants from a number of areas on other plantations where the chlorosis is not followed by a blight.

Soils

The Hawaiian Agricultural Company is located on the southeast slopes of Mauna Loa and cane is grown up to an altitude of 3,000 feet. The soils are principally silts or silty clay loams of excellent physical texture. The location

of the blighted fields is more or less clearly defined, lying within the range of altitude 1,500-2,000 feet. An exception is the Mudflow field. The soil in this field was formed 50-60 years ago by a mudflow from Mauna Loa. It is an entirely different type from most of the other plantation fields and cane grown on this soil has never been affected by the blight. This would seem to eliminate temperature, rainfall or other environment factors, as well as fungi and bacteria, as being primary causes. It is interesting to note that in going over the fields of Hutchinson Sugar Plantation Company, which are also located in the Kau district, in general their soils are quite similar to the Mudflow type. It should also be mentioned that in several areas scattered over this plantation a few plants may sometimes be found with the typical chlorosis, but the blight has not been observed.

For comparative soil studies samples of soil and subsoil were taken from representative fields, both normal and blighted. A description of these is given, followed by a partial analysis in Table 1:

Soil 1—A brown silt loam from Lower Goodale field; cane very badly blighted.

Soil 2—Subsoil to 1.

Soil 3—Brown silt loam from Lower Stone field; cane badly blighted.

Soil 4—Subsoil to 3.

Soil 5—Yellowish gravelly loam from Mudflow field; no blight in this field. This soil is uniform to considerable depth so that no subsoil sample was taken.

Soil 6—Brown silt loam from Lower Wood Valley field; only traces of blight in this field.

Soil 7—Subsoil to 6.

Soil 8—Brown silt loam from Middle Naahala field; a blight field.

Soil 9—Subsoil to 8.

Soil 10—Black silt loam from lower Clover field; no blight in this field.

Soil 11—Subsoil to 10. In this case the subsoil, unlike the blight fields, does not verge off to the yellow type.

Soils 12 and 13—Black silt loam samples from Meyer field. These are both surface samples, 12 from blight and 13 from around normal cane.

Soil 14—Black silt loam from Mission field; badly blighted field.

Soil 15—Subsoil to 14.

Soil 16—Black silt loam from Middle Moaula field; no blight.

Soil 17—Subsoil to 16.

TABLE 1

Analyses of Soils, Pahala Blight

	Air Dry Soil		Soluble in 1 Per cent Citric Acid				Total by Fusion				
Soil No.	Moisture	Volatile and Organic	Silica SiO_2	Lime CaO	Potash K_2O	Phos. Acid P_2O_5	Potash K_2O	Phos. Acid P_2O_5	Acidity pH	Nitrogen N	Remarks
1	7.10	6.93	.58	.62	.043	.0587	.39	.31	7.0	.39	Blight
2*	8.05	8.67	.54	.49	....	.0044	.22	.52	7.0	.45	"
3	17.47	7.53	.50	.37	.024	.0560	.39	.22	6.9	.40	"
4*	19.43	9.91	.44	.39	.029	.0027	.36	.41	6.8	.42	"
8	8.79	11.41	.48	.48	.093	.0072	.50	.47	7.3	.44	"
9*	14.06	13.39	.42	.45	.114	.0042	.31	.48	7.3	.49	"
12	11.53	13.73	.42	.37	.055	.0049	.35	.60	6.8	.50	"
14	10.03	14.97	.48	.54	.035	.0087	.32	.34	6.8	.61	"
15*	14.68	15.12	.46	.45	.036	.0047	.61	.47	6.7	.52	"
6	4.23	5.58	.62	.50	.127	.0123	.56	.60	6.9	.22	Trace blight
7*	15.49	4.31	.54	.49	.106	.0035	1.10	.27	7.0	.37	"
5	19.43	9.54	.48	.25	.095	.0035	.31	.36	6.5	.27	No blight
10	6.92	10.58	.42	.50	.100	.0176	.44	.45	6.6	.40	"
11*	7.25	7.52	.54	.37	.031	.0121	.49	.25	7.3	.34	"
13	15.01	12.22	.40	.39	.034	.0045	.32	.55	6.8	.36	"
16	10.45	13.53	.48	.47	.042	.0067	.55	.41	6.5	.52	"
17*	13.50	12.78	.60	.42	.030	.0046	.33	.62	7.2	.52	"

These analyses would be interpreted as all showing excellent fertility. Available lime and potash are good, as is also the phosphate in the surface soil. The phosphate results are significant in that there is an unusually large decrease in availability in going from the soil to the subsoil. In sampling these soils care was taken that none of the surface soil particles contaminated the subsoil. Since these analyses were made, Mr. Campsie, manager of Hawaiian Agricultural Company, is getting excellent response in many fields by applying superphosphate in the subsoil. This is accomplished by fertilizing in the furrow below the seed at planting time. The writer has noted further indication of the low availability of phosphate in the subsoil at Pahala in the scanty growth on some ridges where the surface soil has been washed off leaving the yellow subsoil exposed. Furthermore, crusher juice analyses recently submitted by Mr. Campsie are low in phosphate, also indicating a low assimilation. Emphasis is placed on this subsoil data because the Hawaiian Agricultural Company is an unirrigated plantation. With an annual rainfall of only 40-60 inches the roots must necessarily feed largely below the surface soil, which is very thin in this district. From the wide variation in soil and subsoil to lower Goodale and Stone fields, which are very bad blight fields, and less variation in Mudflow, Clover and Moaula, it was at first thought that this might have more than passing significance. Heavy phosphate applications have given some response, but only partial improvement in

* **Subsoils.**
All figures except moisture and organic are on water-free basis.

blighted cane. The comparative reaction of these soils is also of interest. In the blighted fields there is little or no difference in reaction between the soil and subsoil, while in the good fields there is notably less acidity in the subsoil as compared to the surface soil. On the whole, these plant food analyses lend little information which is indicative of a causal agent.

In view of the notable response to heavy stable manure, previously pointed out, and partial response to green manure crops, the question of comparative organic content of the soils arose. With this in mind a number of total nitrogen and carbon determinations were made. The carbon determinations are given in the following table while the nitrogen determinations are shown in Table 1:

TABLE 2

Carbon Content of Pahala Soils

	Per cent Carbon
Blight	
Lower Goodale	4.84
Lower Goodale subsoil	5.81
Lower Stone	4.89
Lower Naahala	4.02
Lower Aliona	4.67
Lower Whitney	4.89
Middle Whitney	4.92
Lower Moaula	6.66
Middle Naahala	6.60
Meyer	6.80
Mission	7.17
No Blight	
Upper Mudflow	6.19
Upper Stone	6.30
Upper Whitney	5.49
Upper Clover	6.83
Upper Naahala	5.88
Upper Moaula	8.02
Railroad	5.69
Mill	6.89
Clover	5.80
Middle Moaula	7.12

All are well supplied with organic matter. The average is slightly lower in the blighted fields, but it is believed that the average is more or less nullified by the variation. The total nitrogen content also has no special significance.

Soil Survey: Supplementing the above soil work, Stewart made an extensive soil survey of the plantation, determining the available and total plant foods. The chemical analyses indicated a high degree of fertility. It is significant that on the whole the soils from fields free from blight are slightly more acid than those from the blight fields, although there are variations from this. Other than this possible reaction relation the soil survey gave little information as to the causal factor or factors. In the samples collected in the soil survey there is also shown a greater variation in reaction between soil and subsoil in the sam-

ples from the blight fields. In the blight fields, out of 21 samples in 11 cases the subsoil is more alkaline than the top soil, 5 are less and in 5 cases there is no difference. This is compared with 27 samples from no blight areas in which only 7 samples had a less acid subsoil and the difference covered was far less than in the samples from blighted fields.

The average of the soil reaction data taken from Stewart's report is given in the following table:

	Average pH	Minimum pH	Maximum pH
Surface soil, no blight fields	6.61	6.1	7.3
Subsoil, no blight fields	6.60	6.0	7.3
Surface soil, blight fields	6.80	6.5	7.3
Subsoil, blight fields	6.90	6.3	7.5

Soil Solution: The soil solution was obtained from several representative soils by the displacement method, analyzed and used as a culture medium for the growth of cane shoots. The analyses are given in the following table:

TABLE 3

Composition of Soil Solution

Results Expressed in Parts per Million of Solution

	Lower Goodale Surface	(Blight) Subsoil	Wood Valley Surface	Mudflow Surface	Lower Surface	Aliona Subsoil
Total Solids	1820	842	1760	823	1832	960
Non Vol. Solids	1240	402	1042	528	....	...
Vol. Solids (organic)	580	440	718	295	....	...
Chlorine (Cl)	735	195	310	274	960	172
Nitrate Nitrogen (N)	7	.6	70	17	....	...
Iron and Al. Oxides	3	2	5	3	....	...
Silica (SiO_2)	28	20	47	20	....	...
Lime (CaO)	224	90	204	90	....	...
Sul. Triox. (SO_3)	24	22	30	4	....	...
Phos. Acid (P_2O_5)	1.3	.2	.7	.2	....	...
Magnesia (MgO)	120	49	123	52	....	...
Potash (K_2O)	58	18	74	142	....	...
Soda (Na_2O)	113	56	137	8	....	...

There is a notably high concentration of chlorine in the surface soil of the blight fields. This chlorine is combined as the chlorides of sodium, calcium and magnesium. While we find many irrigated soils higher in chlorine, it is believed that this figure is very high for an unirrigated plantation. At the same time the sulphates are very low.

Plant Cultures: In our investigations on the toxicity of various chemicals on sugar cane a method has been developed for growing cane shoots in water or sand cultures. In accomplishing this the seed pieces are planted in soil and after germination of the buds the shoots are grown to a height of about 8 inches. The shoot is then cut from the seed piece and suspended in water. In the course of a few days roots will develop at the base of the shoot and their vigor will

vary with the nature of the solution in which the shoot is growing. Using this method sufficient soil solution was removed from a blight field soil and subsoil and from the Mudflow field soil and subsoil and used as a medium in which to grow cane shoots.

The shoots were started in the soil solution cultures on January 21. On January 28 there was a marked difference in the appearance of the tops. At this time roots had appeared on all shoots. On February 4, two weeks after starting the shoots in the culture solutions, it was very apparent that some factor was retarding growth in the cultures from Lower Goodale field. The appearance of the plants at this time is shown in Fig. 2.

Chlorine: In view of the higher concentration of chlorine in the soil solution of the soil from blight fields as compared to those on which blight is absent, especially the Mudflow field, a number of samples from representative fields were selected and total chlorine determinations made. The results are given in the following table:

TABLE 4

Chlorine Content of Pahala Soils

Field	Per cent Chlorine	Field	Per cent Chlorine
Lower Goodale	.013	Upper Mudflow	.027
Lower Stone	.003	Upper Stone	.004
Lower Naahala	.003	Upper Whitney	.004
Lower Aliona	.002	Upper Clover	.039
Lower Whitney	.004	Upper Naahala	.050
Middle Whitney	.007	Upper Moaula	.031
Lower Moaula	.002	Railroad	.011
		Mill	.006

These results show a low chlorine content in all fields, but in most cases the total chlorine content of the good fields is higher than that from the blight fields.

Plant Analyses: In view of the fact that the D 1135 variety is notably resistant to blight and Yellow Caledonia is notably susceptible these two varieties were selected for a comparative study. A D 1135 planting may often give a count of 90-100 per cent blight in the early stages of growth and later grow out of it almost entirely. Thus the nature of this resistance in D 1135 was sought in the composition of the plant. The analyses included roots and juice from stalks where plants had reached sufficient age and leaves. In selecting the leaves, the five youngest leaves were taken from the stalk after discarding the rolled or zero leaf. This care was found to be necessary in view of the change in composition of the cane leaves on aging. Juice samples were obtained by pressure without any previous treatment of the stalks, such as freezing to break up the plant cells.

The composition of the leaves is given in Tables 5 and 6, the roots in Table 7, and the juices from the stalks in Table 8. On the whole, the ash is higher in

the blighted leaves and it is recognized that this may be a result as well as a cause. Comparing Yellow Caledonia and D 1135 the general tendency seems to be toward a higher calcium in the Caledonia variety. Comparing the two varieties growing in the same field Yellow Caledonia is higher in chlorides, calcium, magnesium and silica. Comparing, again, blighted and normal leaves it is significant that the young shoots are higher in chlorine than old shoots in the same stool and further that young shoots are often chlorotic in stools in which the large stalks are free from chlorotic leaves. The data as viewed in a general grouping as submitted in Table 5 shows wide variations.

In Table 6 the analyses have been tabulated to show the comparative composition of normal and blighted leaves taken from the same stools or from contiguous stools in the same field. Here, it will be noted, the comparative figures are more consistent. Higher ash, silica and chlorine, and in most cases higher potash, phosphate and nitrogen characterize the blighted leaves. The calcium and magnesium show a different ratio, that is, a higher ratio of magnesium to calcium in the blighted leaves.

The composition of the juice shows again a higher ash in the juice from blighted cane. The silica is lower, calcium and magnesium are lower as per cent of ash, sodium and chlorine are higher and phosphate lower.

The analyses of the roots show wide variations in both blighted and normal plants, and viewing the results as a whole the variations are too great to permit any deductions. On the other hand, on comparing the analyses of contiguous plants in the same field it will be noted that the higher chlorine in the roots from blighted plants is significant.

The question then arose as to the comparative composition of the chlorotic cane at Hawaiian Agricultural Company to that often observed on other plantations on other islands. With the cooperation of Mr. Kutsunai, who was at the time studying the value of sprays and dusts in the control of chlorosis, a number of soil, juice and leaf samples were obtained at Waialua and Ewa plantations.

The samples at Waialua were obtained from two mauka fields, in one of which the chlorosis was notably severe along the unlined irrigation ditches. The Ewa samples were from coral fields. Leaves in both cases showed the characteristic striping. The composition of the leaves and juices is given in Tables 9 and 10, and the soil analyses in Tables 11 and 12. In the latter, other than the reaction, all determinations were made on the soil solution as obtained by the displacement method.

The data on the Waialua plants shows a higher ash in the chlorotic leaves. The lime is higher in the juice from the stalks bearing chlorotic leaves. The same is true of chlorine. The plants from Ewa also show a higher ash in the chlorotic leaves.

TABLE 11

TABLE SHOWING COMPOSITION OF THE SOIL MOISTURE IN WHICH ROOTS ARE GROWING, COMPARING GREEN AND CHLOROTIC CANE

Waialua Agricultural Company

				Composition of the Soil Solution in Parts per Million of Solution									
Field	Leaves	Moisture Per cent in Soil	Reaction of Soil pH	Total Solids	Silica SiO_2	Lime CaO	Magnesia MgO	Sodium Na_2O	Potash K_2O	Carbonate CO_3	Bicarbonate HCO_3	Chlorine Cl	Sulphur Trioxide SO_3
Opaeula 1	Chlorotic	12.6	8.27	2386	24	364	127	220	112	trace	148	112	500
Opaeula 2	Green	23.6	8.03	1610	10	183	74	225	21	none	72	336	134
Opaeula 3	Chlorotic	28.2	7.59	930	18	89	89	149	21	none	30	280	104
Opaeula 4	Green	26.8	7.25	808	36	63	68	104	48	none	30	202	94
Kawailoa 1	Chlorotic	25.8	8.86	1318	30	78	73	387	23	trace	94	514	122
Kawailoa 2	Green	23.8	8.60	1104	20	79	46	333	32	trace	86	386	108

TABLE 12

TABLE SHOWING COMPOSITION OF SOIL SOLUTION IN WHICH ROOTS WERE GROWING, COMPARING GREEN AND CHLOROTIC CANE

Ewa Plantation Company

				Composition of Soil Solution in Parts per Million of Solution									
Field	Leaves	Moisture Per cent in Soil	Reaction of Soil pH	Total Solids	Silica SiO_2	Lime CaO	Magnesia MgO	Sodium Na_2O	Potash K_2O	Carbonate CO_3	Bicarbonate HCO_3	Chlorine Cl	Sulphur Trioxide SO_3
19 c-1	Green	18.6	8.43	9288	50	833	689	1532	68	none	96	3502	640
19 c-2	Chlorotic	20.6	8.43	7970	60	770	547	1104	76	none	62	3254	544
9-1	Green	20.0	7.84	50732	1219	5280	4796	7094	144	none	48	22332	1528
9-2	Chlorotic	24.2	8.50	3948	74	385	155	514	44	none	62	1666	292

All soil analyses show a greater alkalinity where the cane is chlorotic. The concentration of soluble material in the soil solution does not appear to be a factor. A comparison of the total inorganic solids in which the Ewa cane is growing in a soil solution containing approximately 50,000 parts per million solids and the Waialua plants grown in 900-2,300 parts per million is of interest in that there is little difference in the inorganic solids in the cane juice.

Additional relative data is given in Table 13, showing comparative analyses of chlorotic and green shoots from Uba cane grown on the Makiki plots of the Experiment Station. In each case chlorotic and green leaves were taken from

the same stool which had been ratooning just three months. The shoots were about two feet in height and the cane soon after grew out of the chlorosis. These shoots had the characteristic leaf striping, but would be classed as only temporarily chlorotic in distinction to the permanent form which often persists throughout the life of the plant.

It will be seen that there is little difference in these analyses other than the slightly larger amount of chlorine in the chlorotic leaves and this may explain why these plants are only temporarily chlorotic.

As bearing further upon the question of the chloride content of the leaves as well as that of the soil solutions, a set of samples was obtained from Waianae plantation. This information was sought for comparative composition of plants grown on soils in which the soil solution is high in chlorides. The analyses of leaves and juice are given in the following Table 14. In no case was any chlorosis present on these leaves at time of sampling.

Relation of Rainfall and Irrigation

The higher concentration of salts in the soil solution from blight fields as compared to the low concentration in that from the Mudflow field suggested an irrigation test to see if changing the concentration or nature of the soil solution would have a favorable effect on the condition of the cane. This was further suggested by an examination of the rainfall records at Pahala (Figs. 10 and 11). The accompanying graphs were obtained from the plantation and show that in the Wood Valley district, where the cane is less seriously affected by the blight, the rainfall is greater than in the Pahala district where the blight is more severe. Added to this is the greater rainfall in the mauka fields where there is little or no blight. Having no water available for a field experiment this experiment was conducted in tubs.

In a preliminary experiment two stumps of Yellow Caledonia blighted cane were brought from Lower Aliona field, Pahala, to Honolulu and planted in (1) soil from Lower Aliona and (2) in Makiki Experiment Station soil. These plants were brought to Honolulu in November, 1924. They were watered three times a week and in ten days many shoots, all blighted, had developed from both stumps. In one month's time, after planting, all the leaves on the plant growing in Makiki soil had recovered and had developed a normal green color. The conclusion is evident that as soon as the new roots, developed from the old stubble, had started to feed upon the Makiki soil some disturbing factor was corrected or eliminated.

Beginning February 13 the Lower Aliona pot was watered daily. There being no change in the chlorotic stripes on the leaves up to March 23, the amount of water added was increased sufficiently to give a daily leaching out the bottom of the pot. On May 26, two months later, the leaves had practically all recovered from the chlorosis, but the plant was greatly stunted as compared to that growing in the Makiki soil.

A more complete experiment was then planned and conducted by Mr. Thompson at Pahala. Tubs holding 30 pounds of ~~soil~~ were used. Two series of pots were included, one of which was planted with Yellow Caledonia seed and the

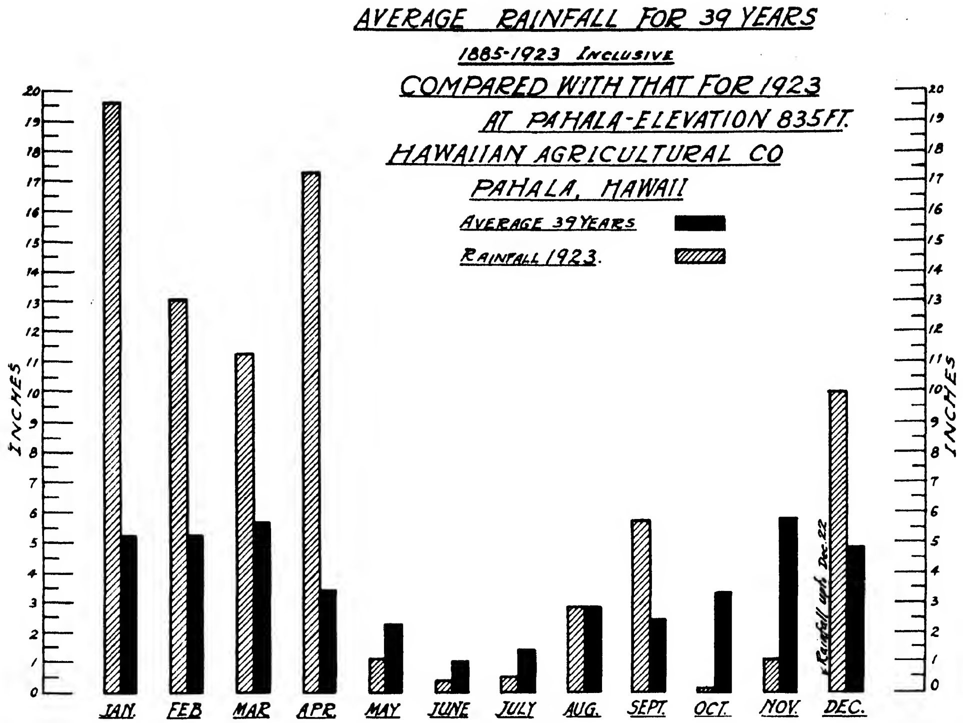
AVERAGE RAINFALL FOR 39 YEARS
1885-1923 INCLUSIVE
COMPARED WITH THAT FOR 1923
AT PAHALA-ELEVATION 835 FT.
HAWAIIAN AGRICULTURAL CO
PAHALA, HAWAII
AVERAGE 39 YEARS
RAINFALL 1923.
INCHES
Rainfall up to Dec. 22
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.

Fig. 10

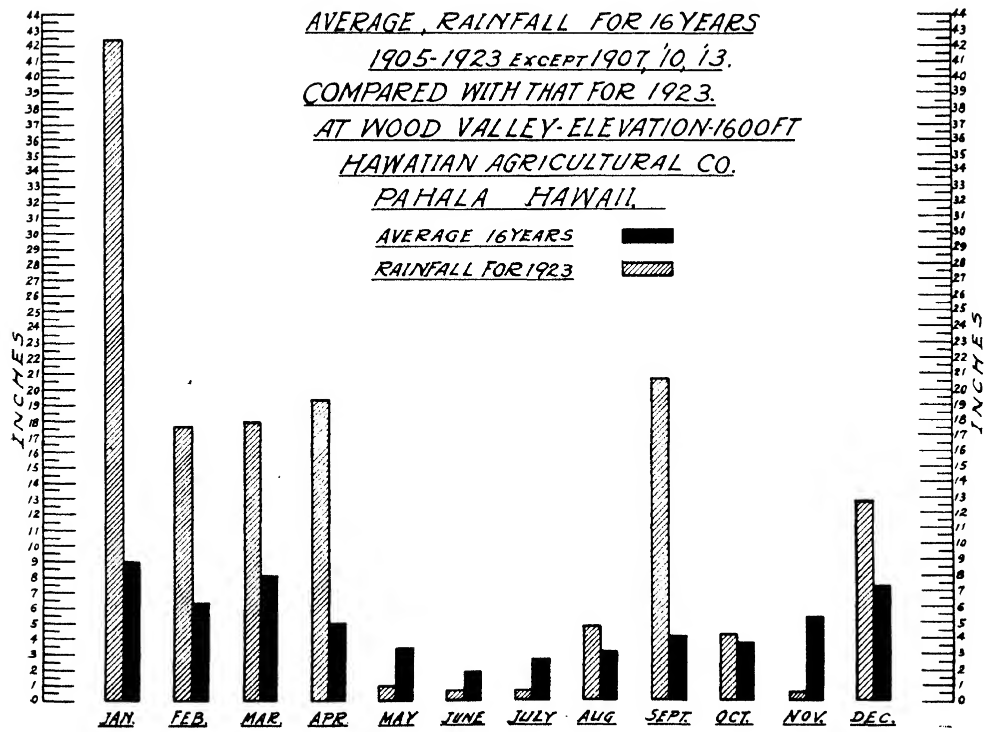
AVERAGE RAINFALL FOR 16 YEARS
1905-1923 EXCEPT 1907, '10, '13.
COMPARED WITH THAT FOR 1923.
AT WOOD VALLEY-ELEVATION-1600 FT
HAWAIIAN AGRICULTURAL CO.
PAHALA HAWAII.
AVERAGE 16 YEARS
RAINFALL FOR 1923
INCHES
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.

Fig. 11

other with cut-back stumps of blighted Yellow Caledonia. The soil used in the pots was taken from Lower Aliona field. The following is a plan of the series:

1. Soil in pots not leached.
2. Soil leached with 5 gallons of water after placing in the tubs.
3. Same as 2 except leached with 15 gallons of water after placing in the tubs.
4. Same as 2 except leached with 25 gallons of water after placing in the tubs.
5. Same as 2 except leached with 40 gallons of water after placing in the tubs.

The blight failed to develop in any of these tubs, checks included. These along with other observations led us to conclude that the blight could not be corrected by the leaching action of irrigation water and that rainfall was not related to the location of blighted fields.

Greenhouse Experiments

In studying a problem such as the Pahala blight it is often essential and of unquestionable value to be able to reproduce it under controlled conditions. For this reason many attempts were made to reproduce the disease in the greenhouse here in Honolulu. Seed planted in Pahala soil at the Station rarely, if ever, develop the blight.

During the time we were investigating the Pahala blight problem, we were also engaged in a study of the effect of saline accumulations upon cane growth on some of our irrigated plantations. The principal salts present in these saline accumulations are the chlorides of calcium, magnesium and sodium. As covering both these problems in one experiment a series of water cultures was carried out. This work has already been published in detail (*The Hawaiian Planters' Record*, Vol. XXIX, p. 410), so that only a brief reference will be made to it here. In these experiments varying concentrations of chloride and sulphate salts were used as media in which to grow cane shoots. In the cultures to which sodium and calcium chlorides had been added there was a distinct yellow striping of the leaves, such as is observed on plants affected by Pahala blight. Neither potassium nor magnesium chlorides nor any of the sulphates produced the characteristic yellow stripes, although there was distinct chlorosis in the magnesium chloride cultures.

The concentrations of calcium chloride and sodium chloride required to produce the yellow stripes in the above experiments were far in excess of that found in the Pahala soil solutions. Also, in growing plants at these concentrations they can only be grown for limited periods, as it is difficult to grow plants successfully for extended periods at high salt concentrations. So that while these experiments indicate that sodium and calcium chlorides may be associated with the yellow striping of cane leaves, the above method falls far short of being an effective method of reproducing the blight for study.

The method of growing cane in water and sand cultures as developed by the writer, was tried in tumblers of soil. Eight-inch cane shoots were cut from seed pieces and transferred to small tumblers of Lower Aliona soil. It was thought

that the absorption of the soil solution at the base of the shoot, which sustains the plant in this method until roots develop, might reproduce the physiological disorder associated with the blight. However, all these tests were negative, that is, blight developed in none of them. The same was repeated with the plants grown under a bell jar so as to cut down the rate of transpiration. Many afternoons are overcast in the Pahala district, lowering the rate of transpiration with a slight increase in humidity. But in these experiments the plants again retained their normal green color. Still another modification in this method was made by partially shading the bell jar, but still no development of the blight. In another attempt the shoots used were lalas cut from a blighted stalk and the leaves were already in a state of itiolation. These lalas were about 8 inches in height. The old leaves retained their chlorotic stripe, but all the new leaves came out free from chlorosis.

Another experiment somewhat similar was conducted on a larger scale, using pots holding 10 pounds of soil. The soil from Lower Aliona field, and taken from one of the worst spots on the plantation, was again used. The following is a plan of this experiment:

1. Four check pots.
2. Two pots to which 5 grams sulphur had been added.
3. Two pots to which 10 grams sulphur had been added.
4. Two pots to which 20 grams sulphur had been added.
5. Two pots to which 40 grams sulphur had been added.
6. One pot irrigated with 50 p. p. m. $CaCl_2$ solution.
7. One pot irrigated with 100 p. p. m. $CaCl_2$ solution.
8. One pot irrigated with 250 p. p. m. $CaCl_2$ solution.
9. One pot irrigated with 500 p. p. m. $CaCl_2$ solution.

The irrigations with calcium chloride solution were made twice a week for the first month and then discontinued, tap water being used from this date. The plants were shoots 8-15 inches in height cut from seed pieces and planted in the pots. This experiment extended over the period of June 25 to November 2, at which time the experiment was discontinued. At this time only one plant had developed the blight and that was one of the four check pots. Apparently the disorder connected with the blight is not associated with a concentration of chlorides in the soil, although this tells us little about the effect of absorption in varying amounts.

Sand Cultures: In the large number of experiments conducted by the writer in which sugar cane has been grown in water cultures it has been often noted that the characteristic striped chlorosis will develop in the cane plant. This condition occurs irregularly, that is, it may be present in several plants, one plant or none at all in a series. It always occurs in solutions to which various nutrients have been added, that is, cane may be grown in distilled water containing no nutrients and no iron, other than that from contamination, as long as six months and retain a healthy green appearance. If to this solution nutrient salts are added, leaving off iron, chlorosis will develop and will often develop as in the cultures mentioned above even where small amounts of iron have been added. This would indicate that under certain conditions either the iron requirement of the cane is increased or where other basic nutrients are present the iron is unable

to function, as the requirement may be reduced to a minimum by leaving basic salts out of the nutrient solution and using distilled water only.

In order to throw further light on this phase of the problem the following set of sand cultures was grown. The cane used in this experiment was Yellow Caledonia and shoots were prepared in the usual manner, cut from the seed piece and transplanted to silica sand. The following nutrient solution was added to these plants as needed:

15 cc. per litre of .2 normal calcium nitrate.
10 cc. per litre of .1 normal ammonium nitrate.
8 cc. per litre of .1 normal potassium chloride.
8 cc. per litre of .2 normal magnesium sulphate.
1 cc. per litre of 8.3 grams calcium phosphate (mono).
Trace ferric citrate.

The following is a plan of the experiment:

Nutrient solution as above leaving out the iron citrate.

Nutrient solution as above, but substituting potassium sulphate for the chloride so as to have the nutrient as free of chlorides as possible.

Nutrient solution as in 2 with an addition of 100 cc. of a $CaCl_2$ solution containing 10 grams chlorine per litre.

Nutrient solution as in 1 with an addition of the same amount of $CaCl_2$ as in 3.

Nutrient solution same as in 1 plus 25 cc. of a .2 per cent solution ferric chloride per two litres.

Nutrient solution same as in 1 plus 25 cc. of a .2 per cent solution of ferrous sulphate per two litres.

Nutrient solution same as in 1 plus 25 cc. of a .2 per cent solution of ferric citrate per two litres.

Nutrient solution same as in 1 plus 100 cc. of $CaCl_2$ solution plus 25 cc. of a .2 per cent ferrous sulphate per litre.

In this experiment only the iron-deficient cultures developed chlorosis and indicated the same relationship already described.

Planting Diseased Seed: In planting seed from cane grown on the Experiment Station fields in Pahala soil the leaves have never developed the blight. In view of this a number of plantings were made in pots of Pahala soil and Station soil, using top and body seed from blighted cane at Pahala and comparing this with the same seed obtained here at the Experiment Station. In the first experiment comparison was made with body seed. Three pots holding 40 pounds of soil were filled with soil from Lower Aliona field, Pahala, and one pot with soil from the Makiki plots of the Experiment Station. Two Yellow Caledonia body seeds from Lower Aliona field and two from Makiki were planted in each pot. In the Pahala seed the buds rotted soon after germination in every case except one which grew to a height of 16 inches, although badly attacked by the blight. By germination it is meant that the buds reached a height of about one-half inch and then rotted away. The Makiki seed made very poor germination, but several grew to normal shoots with no appearance of chlorosis. All seed planted in Makiki soil made good germination and there was little or no difference between the Pahala seed and Station seed. The results of this experiment are shown in Fig. 3.

In a second experiment top seed was used. Plantings of Pahala top seed were made comparing germination in Makiki soil and Lower Aliona soil. The Pahala top seed planted in Lower Aliona soil came out 100 per cent blighted and continued so. The Pahala top seed planted in Makiki soil came out practically 100 per cent blighted, but in two weeks' time 90 per cent of the plants had thrown off the chlorosis and while somewhat undersized were free from outward appearance of the blight. This would indicate that the conditions operating to produce blight are present in the seed from blighted plants and that seed selection should be made if every possible means of combating the disease is to be utilized. It is also shown in this experiment that the disease may be reproduced for study by planting diseased top seed in pots of soil from diseased areas in the field.

As another method of reproducing the disease for study a number of diseased stumps were dug up at Pahala, the tops cut back and the whole transferred to Honolulu and replanted in soil from blight fields. New lalas developed from the buds on the cut-back stalks and all were badly blighted.

Hoffer, in studying the toxic effect of chemicals upon corn, introduced these chemicals into the stalk by inserting a tube into the tissues. This is accomplished by puncturing the stalk with a sharp cork borer. The tube is then inserted approximately to the center of the stalk and then slightly exserted to form a small reservoir from which the solution will be absorbed by the plant. Measured amounts of the solution are then poured into the tube. By this method a number of chemicals were fed by absorption into the stalks of blighted plants.

For this purpose a number of diseased stumps were planted in Lower Aliona soil and when the lalas on the stalks had reached a length of about 6 inches the tubes were inserted below the nodes on which the lalas were located. This is illustrated in Fig. 4. To one stalk a 1 per cent solution of ferrous sulphate was added, to a second a 1 per cent solution of $CaCl_2$, to another a N/20 solution of sulphuric acid, and to still another a 1 per cent solution of sodium carbonate. The leaves growing from the stalk receiving ferrous sulphate soon turned to a normal green and were the healthiest of the series. The sulphuric acid, probably by permitting a greater functioning of the iron in the plant, also showed a notable improvement in color although not equal to the ferrous sulphate. Both calcium chloride and sodium carbonate were absorbed only to a very slight degree but seemed to intensify the blighted condition of the leaves. The appearance of the roots is shown in Fig. 8.

It is believed that this little experiment shows quite conclusively that some factor interfering with the proper functioning of the iron is one of the most important factors associated with the blight. This is further indicated in the illustration, where it is shown that a stimulation in root growth also resulted from the increased leaf development obtained by the absorption of chemicals into the stalk.

Field Experiments and Sulphur Fertilization

When our investigation had reached a point where sufficient "clews" had been developed to warrant field experiments these were planned by the writer and Mr. Thompson, agriculturist at the Hawaiian Agricultural Company, and installed by Thompson. Sulphur was applied in an attempt to offset the greater absorption of chlorides by the plant provided this factor was related; to increase

the acidity of the soil and thereby the solubility and availability of acid reacting salts, primarily iron. Most chlorotic troubles are associated in some way with either an iron deficiency or a failure of iron to properly function within the plant. While our plant analyses did not signify any iron deficiency within the plant the soil analyses did show in general a higher acidity in the soil from the best fields. As a further basis for adding the sulphur there was the previous experiment already mentioned, which showed a temporary response to pouring iron sulphate solution around the roots of blighted plants. Also in our field experiment there were included heavy applications of potassium sulphate and ammonium sulphate as being milder acid residual fertilizers and as furnishing the sulphate radicle. Heavy phosphate applications were also included in an attempt to determine if a greater root development in the subsoil would increase the resistance of the plants.

These experiments were installed in the early spring of 1925 and the sulphur plots came up practically entirely free of blight and showed a great improvement in vigor, color and size, as illustrated in Fig. 5.

The effect of sulphur is further illustrated in a pot experiment conducted at the Experiment Station. A number of diseased stumps were cut back, brought to Honolulu and replanted in Pahala soil. To two of the tubs sulphur was mixed with the soil before planting, at the rate of one ton per acre. The experiment was started September 12. On October 8 the plants growing in the sulphur pots were far more vigorous and larger in size, but still had a few yellow stripes on the leaves. By October 15, this striping had entirely disappeared and the plants were normal in color and unusually vigorous. In the meantime all the checks were badly blighted and stunted in growth. This experiment was continued until November 15, at which time the plants were removed from the pots in order to observe the condition of the roots. The comparative growth of the plants in this experiment is shown in Figs. 6, 7 and 8.

It will be noted in these illustrations that in correcting the chlorosis in the leaves by injecting iron sulphate into the stalk there was a corresponding increase in root development. While the roots on this plant were not so vigorous as those on the plants grown in sulphured soil, nevertheless it is apparent that in correcting the chlorosis there is a general improvement in the condition of the plant as a whole. The conclusion is evident that the chlorosis is a primary factor in the general breakdown known as Pahala blight. It is, however, recognized that there appears a possibility of one or more other factors being associated and this is based on the remarkable stimulation in growth of so-called resistant varieties resulting from the sulphur application.

Pot Experiments With Rice

In the study of chlorosis by various investigators the rice plant, which is very susceptible, has found wide application. In view of this a pot experiment was conducted to determine whether the chlorosis and blight would be reproduced upon this plant. If so, being a short growing plant, it would have permitted a more rapid study of the problem. Clay pots holding 10 pounds of soil were filled with soil from Lower Aliona field, Pahala, and the following series of treatments applied:

1. Sulphur, 4 grams per pot.
2. Sodium sulphate, 4 grams per pot.
3. Sodium carbonate, 4 grams per pot.
4. Ammonium sulphate, 4 grams per pot.
5. Calcium carbonate, 4 grams per pot.
6. Sodium chloride, 4 grams per pot.
7. Sodium nitrate, 4 grams per pot.
8. Calcium chloride, 4 grams per pot.
9. Control, soil not treated.

These various chemicals were well mixed with the soil before planting. The chemicals were applied September 21 and planted to rice on September 22. On October 8, when all plants had reached a height of six inches, one series was changed to "wet land" culture and from this date was kept in standing water, while the second series was continued as a dry land experiment.

Throughout the experiment the ammonium sulphate pots were the most vigorous plants in both series, with the sulphur pots a close second up to the period at which in the wet land pots the lack of nitrogen retarded the growth. From this period it was surpassed by the nitrate pots. It is significant that in the dry land series the ammonium sulphate and sulphur treatments were the only pots which produced mature plants. All the rest died in about two months. The pots were photographed January 12, and are shown in Fig. 9.

Chlorosis

Chlorotic diseases of plants are often noted on agricultural crops and the conditions under which chlorosis is developed have been intensively studied. Most cases may be classified under one of the three following heads:

1. Diseases caused by bacteria or fungi often develop chlorosis. Mosaic disease is an illustration. Pahala blight has also been mentioned as a case in point, but this has been open to question.

2. Poor drainage and soil aeration developing to a point of toxicity or stagnation are often cited as causes of plant yellows.

3. Physiological or nutritional disturbances. So-called lime induced chlorosis, which is quite common in many plants grown on calcareous soils, is an example of this class.

As a matter of fact it is within the latter class that most chlorotic diseases arise. The apparent disease is merely an outward manifestation attending one or more physiological disturbances. In the majority of such disturbances the final causal factor is a deficiency of iron in the soil or in the plant.

In the cases covered by this investigation there is no indication of any infectious disease. The plants from Ewa and Waialua plantations gave no indications of being attacked by bacteria or fungi. The chlorotic plants at Pahala do finally in many cases succumb to the attacks of fungi. How great a factor the fungi are has not been determined, but in this work it has been shown that the disease may be controlled without recognition of the attacks of organisms. Also there was no indication of poor drainage in any of the areas covered here. In fact the Pahala soils are of unusually excellent physical texture. Evidence therefore shows unquestionably that the chlorotic conditions covered in this study fall in the class including physiological or nutritional disturbances.

Review of Literature

No attempt will be made at a complete review of the work on chlorosis, but merely to present several studies which are of especial interest in their relation to our own problem.

Gile[1], in a survey of chlorotic areas of sugar cane in Porto Rico, found it confined to very calcareous soils, but also noted that not all cane on such areas was chlorotic. Furthermore, he observed no chlorotic cane was to be found on slightly calcareous soils. In fact he mentions that the cane seems to favor a neutral or slightly alkaline soil where alkalinity is due to lime. These chlorotic leaves turned green in a few days after brushing with a solution of ferrous sulphate, but in several brushings were killed. In later experiments on these chlorotic areas[2], stable manure, stable manure mixed with ferrous sulphate, and spraying with a solution of ferrous sulphate were beneficial. Gile states: "There does not seem to be any definite period in the growth of the plant when it becomes chlorotic. Sometimes cane which has just sprouted is blanched and at other times the cane is unaffected until eight months old. As a rule ratoons seem to be affected more strongly and generally earlier than plant cane." All stages of chlorosis have been observed in Porto Rico, "leaves entirely ivory white, some with midrib green and others with the veins green, but the parenchymous tissue colorless." This description would apply to many chlorotic local calcareous areas, but hardly to Pahala.

Gile also studied the chlorosis of pineapples[3] in Porto Rico which he again found to be confined to calcareous areas. He found this to be a result of faulty nutrition induced by an excess of lime. According to Gile, Gris as along ago as 1843 showed that by treating chlorotic plants with ferrous sulphate they resumed their normal green color. This method as a control for chlorosis on grapevines has also been applied extensively in France and Germany. Gile applied it to chlorotic pineapples, with complete recovery of the plants.

The agriculturists at this Station have shown that chlorotic cane on a number of fields on Oahu responds remarkably to applications of iron sulphate to the leaves (Director's Monthly Report for October, 1925).

In attempting to explain this property of calcareous soils, Gile showed experimentally that neither the alkalinity nor the excessive amounts of lime were alone the cause of chlorosis, but rather it was a combination of the two factors. The ash analyses of plants showed an increased absorption of lime, creating a necessity for an increased quantity of iron and rendering average amounts of iron inactive. Sugar cane leaves, analyzed by Gile[4], showed a lower per cent of iron in the ash of chlorotic leaves (as per cent ash). He concludes from this that the chlorosis of sugar cane is accompanied by a lack of iron which is caused by a depression of the availability in the soil.

This study of chlorosis at the Porto Rico Station was later continued by Willis[5] and somewhat modified Gile's conclusions in that there was found associated with the lime in these soils the additional effect of the salts added as fertilizer. He cites the work of Kossowtsch and of Mazé, which demonstrated a change in reaction resulting from the unassimilated residue of fertilizer salts. Ammonium sulphate tended to produce an acid reaction and sodium nitrate an alkaline reaction. It will be noted from this that where nitrate of soda is applied there will be a lesser availability of iron.

In experimentally studying this point Willis showed that nitrate of soda, calcium carbonate and ammonium phosphate, which in themselves or by virtue of an unassimilable iron are the cause of the precipitation of iron, were associated with chlorosis, while the plants supplied with ammonium sulphate were a normal color. From this he suggests that the unassimilable residues are primarily the cause of chlorosis and that the reaction of the soil is a secondary factor.

McCall and Haag[6] at the Maryland Experiment Station have shown that in sand cultures chlorosis may develop where calcium or sodium nitrate is used within the reaction range of pH 4.02 to 7.0. Adding iron to the cultures at this reaction did not improve the condition of the plant, but by increasing the reaction with sulphuric acid the plants became a normal green color. It is therefore shown that chlorosis or faulty metabolism resulting in chlorosis may be possible at reactions below neutrality, and since the reaction of many of the Pahala soils is on the acid side of neutrality this is a case in point.

As showing the complexity of chlorosis the work of Kelley[7] and Cummins on the mottled leaf of citrus trees may be mentioned. In this case conditions are directly opposite, as there appears to be a *deficiency* of calcium or an inability of citrus trees under certain conditions to obtain their lime requirements.

Malherbe[8] has made some very interesting observations in South African plum and apricot orchards, which appear to be somewhat related to Pahala conditions. He noted in orchards affected by chlorosis that the condition was always intensified following heavy applications of basic alkaline fertilizers. Surface soil samples taken from about healthy and chlorotic trees showed a greater acidity in the former. These soils were not calcareous soils, and like the Pahala soils, none strongly alkaline and some slightly acid. On these chlorotic trees iron sulphate spray killed the leaves and when applied to the soil gave only temporary improvement. On the other hand, changing from basic fertilizers, primarily basic slag, to residually acid fertilizers such as ammonium sulphate, superphosphate and potassium sulphate, these orchards were completely restored to normal. He advised the use of sulphur as a fertilizer in acute cases.

In Antigua, West Indies, cane fields, what are known as gall patches, are often observed. The plants on these areas are often chlorotic and the soils calcareous. Tempany[9], after a study of this problem, suggested that this condition was not due to excessive lime, but to sodium carbonate formed by a reaction between the lime and the saline material, principally sodium chloride, in the soil solution. The gall patches showed a greater alkalinity than the surrounding areas in which cane made good growth.

It is evident from a review of the literature that the results obtained upon the Pahala soil by sulphur fertilization are not only theoretically sound, but are also supported by other investigations.

The results obtained in our rice experiment are rather striking and it is of interest to compare this with the work of Gile, Willis and Carrerro, already cited. During the early stages of growth the submerged pots showed active stimulation from the sulphur treatments. At the time the plants were photographed the sulphur pots were about the same as the checks and plainly showed the effect of the lack of nitrogen. The value of sulphur and ammonium sulphate, and the

same might also apply to any acid fertilizer, is shown in the "dry land" pots. The check plants and all those treated with alkaline fertilizers made only a short growth, eight inches, and then died. Both the sulphur and ammonium sulphate would increase the availability of iron provided this was a retarding growth factor, while in the submerged pots there would be a reducing environment conducive of maximum availability of iron under the conditions existing even in the presence of alkaline salts. Other than the check pots and the sodium nitrate pots there was little chlorosis of the rice plants. Preceding death the leaves turned a brownish color rather than the characteristic chlorotic yellow.

As a further step in the study of this problem some explanation of the conditions which operate following sulphur fertilization was sought. Comparative analyses of chlorotic leaves from check plots and green leaves from sulphured plots in the field experiments were made. Also a short soil study was conducted. The comparative composition of the leaves is given in the following Table 15:

The first column, showing the comparative weight of the leaves, is of especial interest and shows very clearly the relative stunting in growth resulting from attacks of the blight. The reduction in leaf area in blighted plants even in the absence of chlorosis would materially reduce the sugar-producing activities in the leaves. In general, the sulphur has materially reduced the ash content of the leaves; the potash and chlorine also show some reduction. Other than this, taking into consideration the wide variations, there is little difference in the composition of the leaves. The iron determinations do not indicate that the iron content of the leaves has been increased by the sulphur, but rather making the deduction from averages there is less in the leaves from the sulphured plots. This applies both to the Yellow Caledonia and the D 1135. In considering these results as relative composition of the ash, Yellow Caledonia, the susceptible variety, shows a higher silica, lime and sulphate in the sulphured plants.

The soil changes induced by sulphur fertilization have been the basis of numerous investigations. Sulphur itself is more or less inert and its action in the soil follows its oxidation, usually bacterial, to sulphuric acid. Lipman has suggested using this property of sulphur as a means of increasing the availability of phosphate. Others have suggested sulphur as a neutralizing agent for alkali in alkali soils. Numerous references could be cited in which response to sulphur fertilization has been obtained, but such have been on sulphur deficient soils. There is no deficiency of sulphur as a plant food in Pahala soils. In fact the Mudflow field which has always been free of blight is lower in water soluble sulphates than the blighted fields. The excellent response to sulphur at Pahala is not related to any deficiency of sulphate as plant food.

Another application of sulphur to agriculture has been shown in adjusting soil reactions to ranges most favorable to definite plants or crops and unfavorable to injurious organisms. The control of potato scab by means of sulphur fertilization, by which the reaction of the soil is increased to a point where the fungi cease to operate, is a case in point. Whether the results of the sulphur treatments at Pahala are in any way associated with the control of fungi has not been determined. It is, however, significant that the leaves of the plants growing on the sulphured plots are free from any visible attacks of organisms in direct contrast

to the plants in the check plots. It is believed, however, that this is due to the greater resistance or vitality of the plants on the sulphur plots.

Some indication of the chemical changes brought about in the Pahala soil is shown in the following tables. This soil is from one of the worst spots in Lower Aliona field and is that used in the pot experiments. The sulphur had been well mixed with the soil and kept at optimum moisture content for four months previous to the analyses.

In Table 16 is given the solubility of the more important soil constituents in 1 per cent citric acid, which solvent has been extensively used by this laboratory in estimating soil constituents available to sugar cane. In Table 17 is given the composition of the soil solution obtained by the displacement method. This solution represents that in which the plant roots would actually be growing in this soil.

TABLE 16

Comparative Composition of Citric Extracts

Expressed as Per Cent Dry Soil

	Check	Sulphur
Silica (SiO_2)	.507	.520
Manganese oxide (Mn_3O_4)	.050	.040
Calcium oxide (CaO)	1.194	.962
Magnesium oxide (MgO)	.289	.334
Sulphur trioxide (SO_3)	.203	1.220
Potash (K_2O)	.105	.059
Phosphoric acid (P_2O_5)	.2045	.1380
Soil reaction pH	7.16	5.39

TABLE 17

Comparative Composition of Soil Solution

Expressed in Parts per Million of Solution

	Check	Sulphur
Total solids	2440	7440
Non-volatile solids	1316	5940
Volatile solids	1124	1500
Silica (SiO_2)	25	65
Iron-aluminum oxides (Fe_2O_3-Al_2O_3)	5	9
Phosphoric acid (P_2O_5)	.4	1.5
Manganese oxide (Mn_3O_4)	none	trace
Lime (CaO)	248	940
Magnesia (MgO)	145	941
Sulphur trioxide (SO_3)	223	3635
Sodium (Na_2O)	417	566
Potash (K_2O)	135	108
Chlorine (Cl)	140	272
Bicarbonates (HCO_3)	36	18
Carbonates (CO_3)	none	none
pH of soil suspension	7.16	5.39
pH of soil solution* (immediate)	8.18	5.2–6.0
pH of soil solution* (next day)	8.18	8.01

* The reaction of the soil solution was determined immediately after extraction, without allowing contact with air, beginning with the first 5 cc. and continuing to 100 cc. The reaction of these separates varied irregularly from 5.2 to 6.0. After standing 24 hours the entire soil solution extracted had changed to 8.01. The usual method of determining soil reaction involves the suspension of the soil in water at the ratio of 1-3 and this figure is that given in the table as soil suspension.

There is little of importance shown in the 1 per cent citric acid extracts other than that the sulphur has undergone rapid sulphofication as shown by the increase in acidity. On the other hand, the concentration of all constituents with the exception of potash and bicarbonate in the soil solution has been increased. The difference in availability or solubility of iron would be greater than that indicated by the analyses, as at the reaction developed by the sulphur the iron would be combined rather rapidly with phosphate which is present in large quantities in this soil. The data show beyond question that comparatively large amounts of soluble iron would be continuously supplied to the roots in the environment created by the sulphofication of the sulphur.

As showing how closely related the response of blighted plants is to the change in reaction wrought by the sulphur, the following observations are of interest. In the sulphur plots there are to be found occasional stools which are chlorotic yet not blighted. Samples of soil were taken about these plants for comparison with that taken directly around plants entirely free from any chlorosis. These samples are from Lower Aliona field, and the soil samples are from neighboring stools:

Good plant, sulphur plot, pH	5.56
Chlorotic plant, sulphur plot, pH	7.08

From this it is evident that the inability to thoroughly incorporate the sulphur with the soil has permitted scattered stools to fail to respond to the sulphur treatment. Anent this significance of soil reaction, another set of soil samples was taken from an area in Middle Naahala field, untreated soil, where there was a spot of badly chlorotic cane surrounded by plants which at least at the time of sampling were not showing any indications of a disturbance. The pH of the soil around the chlorotic cane was 7.33 while that around the good cane was 6.66. The preceding data would also account for the variable results given in the reactions obtained in the soil survey, to which attention was called in the discussion of this data, and give sufficient grounds for accepting averages in spite of the variations. Three samples of soil taken within an area of one acre in Middle Naahala field showed a variation in reaction of pH 6.06 to pH 7.33 and as stated above there appeared to be greater soil acidity in the good spots.

Discussion

The results indicate that the chlorosis associated with Pahala blight is caused by an entirely different set of conditions than that of Ewa and Waialua plantations. At the latter there are two definite forms, a temporary and a permanent chlorosis. The former, which occurs only on young ratoons, may be explained on the following theory: Nitrogen is held off maturing cane for a considerable period preceding the harvest. The nitrogen content of the soil is therefore at a minimum until the regular fertilization of the ratoons. Also as soon as the cane is harvested the soil moisture evaporates rapidly from the soil surface, increasing the concentration of soluble material around the roots of the new forming shoots. The young shoot therefore begins to feed upon a nutrient solution high in basic material and low in nitrogen, a ratio usually conducive of chlorosis. This is shown

by the high ash content of the yellow leaves and further by the fact often noted on the plantations that early fertilization or even early irrigation of the ratoons is of value as a corrective measure.

The permanent forms of chlorosis on these alkaline and calcareous areas appear to be a result of the lower availability of iron in the soil and conditions in the plant which operate against its activity, namely, a greater absorption of inorganic material by the plant and transported to the leaves. As Kutsunai has shown, these plants may be restored to normal by treating the leaves with iron sulphate. In the alkaline fields where coral is absent the plants should respond to acid fertilizers such as sulphur or ammonium sulphate. As a matter of fact, Denison, of the agricultural department, in an observation test showed that the plants at Waialua plantation responded to sulphur fertilization in one month. This is much slower than treating the leaves, but it is permanent. Whether the use of acid fertilizers could be extended successfully to the coral fields is open to question, but theory favors the use of ammonium sulphate in preference to nitrate of soda on such fields.

The Pahala fields are entirely free of coral. Their reaction is in no case strongly alkaline. In fact many of the soils in which the cane is chlorotic are slightly acid. As a related case here in the Islands, the chlorosis of pineapples on the manganiferous soils may be cited. These soils are in all cases acid soils, yet pineapple plants are almost universally chlorotic on such areas. It should be mentioned, however, that cane has never been known to develop chlorosis on the manganese soils and the writer has often seen it growing on such types. The Pahala soils are the only soils on record in which sugar cane has shown chlorosis on acid soils.

One very significant observation in our study of the problem was that the soil solution always appeared to be more or less colloidal, which, however, is not true of the soil solution from the Mudflow field which has always been entirely free from blight. In using the soil solutions as culture media in which to grow cane shoots it was noted that after a certain period there was a coagulation of this colloid and from this time the roots developed rapidly. It was suspected at the time of the experiments that this was colloidal silica. Since then it has occurred to the author that this may have been colloidal iron or a colloid which interferes with the assimilation of iron by the roots. Gile[10] has shown that rice plants cannot assimilate colloidal iron. In our own soil work we have shown that between reactions of pH 6.0 and 7.5, which range covers most of the Pahala soils, iron (ferric) is present in solution only in the colloidal form. There would be little opportunity for ferrous iron to be present in such open soils as those at Pahala. There is a strong possibility, therefore, that conditions in some of the Pahala soils operate toward minimum availability.

In soils within the reaction range at which iron is not in solution plants depend upon the carbon dioxide liberated in root respiration to obtain such insoluble materials. Carbon dioxide, the product of root respiration, is directly dependent upon the normal development of chlorophyll in the leaves. Chlorotic leaves will operate toward retarded root respiration and will limit the rate and amount of carbon dioxide produced by the roots. It is therefore evident from

this that the poor leaf development on the plants at Pahala will limit root development, promote a general breakdown of the plant and predispose it to a ready invasion of the fungi which appear to be associated with the final blighting of the cane. It is thus shown that chlorosis produced by malnutrition in the leaves is reflected back to the roots. We have thus far been unable to discover any toxic condition in the soil which would account for the poor root development in blighted plants. All evidence to date strongly indicates that the poor root development is secondary to the disturbance in the tops and that roots are just as dependent upon the food supplied to them by the leaves as they are upon that which in themselves they absorb from the soil.

It is believed from our observations with sugar cane that chlorides, probably only the sodium and calcium chlorides, are in some way associated with chlorosis not as a question of concentration in the soil solution but as an unbalanced absorption by the plant. The chlorosis, an iron deficiency, is merely the final outward manifestation of such a disturbance. In our field experiments in which D 1135 variety was used, which variety has always been considered blight resistant, we obtained remarkable response to sulphur fertilization. This response was obtained on blighted as well as unblighted plants in diseased areas. It is evident from our field experiments that D 1135 does not possess the degree of resistance which has been credited to it, although it is more resistant than any other variety. This is probably due to the fact that the outward manifestation of the blight, the chlorosis, is often lacking or is thrown off at an early stage in its growth. In a replanted area in Lower Aliona there were many D 1135 plants in the control, unsulphured areas, which were not chlorotic and yet were no larger in size than the chlorotic plants, while in the sulphured area the plants were uniformly much larger in size and of a richer green color.

Another indication that factors other than the reaction range at which iron is at lowest availability are involved, is that at this same reaction where the cane is growing in distilled water chlorosis does not develop. It develops only when there are present soluble nutrient salts which operate against the activity of the iron.

Conclusions

1. Pahala blight is the result of a physiological or nutritional disturbance induced by soil conditions.

2. With the exception of phosphate in the subsoil, plant food availability is very high in Pahala soils.

3. The principal difference between the soils from blight and no blight fields is the slightly lower hydrogen ion concentration and in the lower hydrogen ion concentration of the subsoil as compared to the top soil in the former.

4. Comparative plant analyses indicate that a greater ash and chlorine content in the blighted plants is related to the chlorosis.

5. In a comparison of chlorotic plants from coral and other alkaline soils with plants grown on Pahala soils a similarity in composition was noted. Wide differences were, however, shown in the soil environment. The outward manifestation, namely, chlorosis or iron deficiency, is similar. The causal environment is different.

6. The disturbing factor may be carried in the seed, which, however, soon disappears if planted in good soil. If planted in blight soil the plant is weakened from the germination point.

7. Seed from blighted plants should never be used, in view of their lower vitality.

8. Sulphur fertilization entirely corrects the causal environment associated with Pahala blight, in that it increases the acidity of the soil and thereby the availability of the acid reacting salts, notably iron. A greater efficiency of iron in the plant is also produced.

Acknowledgments

The writer is indebted to other members of the Station staff for their interest in this work and especially to the plantation manager, James Campsie, and the plantation agriculturist, J. C. Thompson, for their hearty cooperation and encouragement.

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Fig. 1 A

Fig. 1. B

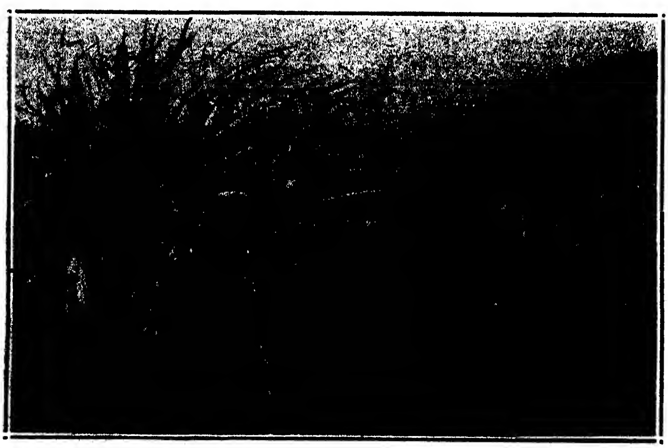

Fig. 1. C

Three views of Yellow Caledonia cane affected by Pahala blight. A and B show the disease quite uniformly scattered over the field. C shows a good stool in badly blighted field.

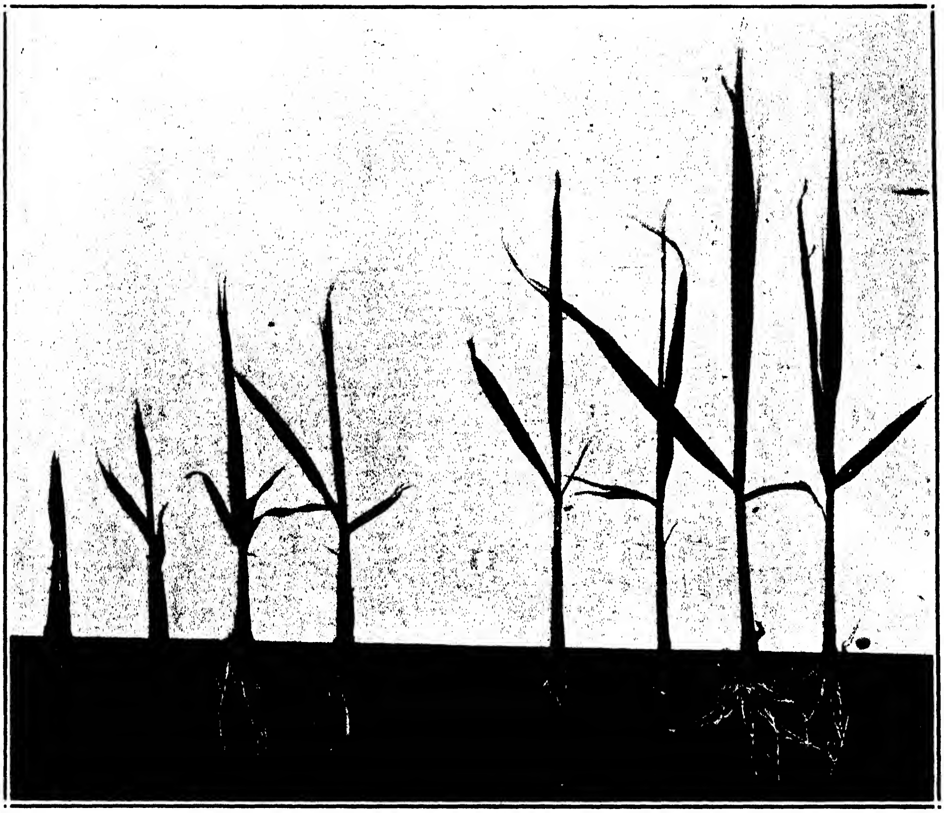

Fig. 2. Showing growth of cane shoot, two weeks period, in soil solutions. Reading from left to right: 1—Yellow Caledonia, soil solution from lower Goodale. 2—Yellow Caledonia, subsoil solution from lower Goodale. 3—Yellow Caledonia, soil solution from Wood Valley. 4—Yellow Caledonia, soil solution from Mudflow. 5—D 1135, soil solution from Lower Goodale. 6—D 1135, subsoil solution from Lower Goodale. 7—D 1135, soil solution from Wood Valley. 8—D 1135, soil solution from Mudflow.

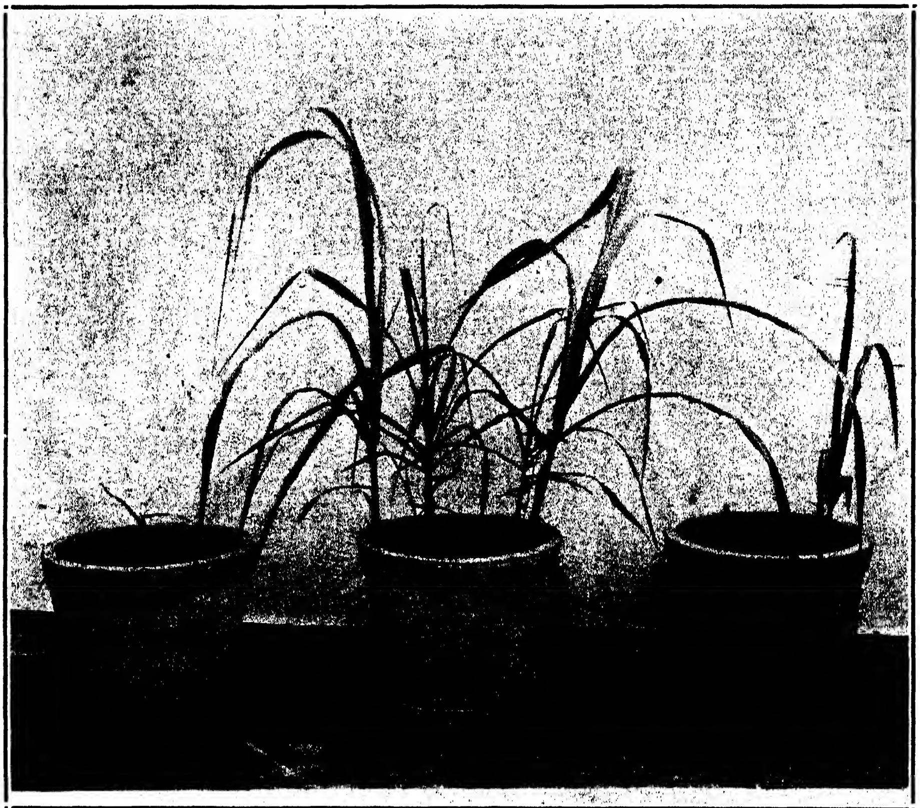

Fig. 3. Showing comparison of Pahala and Station seed in Pahala and Station soil. Left—Pahala seed—Pahala soil (typical blight). Center—Left—Pahala seed—Station soil; right—Station seed—Station soil. Right—Station seed—Pahala soil.

A

B

Fig. 4. Showing method of feeding chemicals into the cane stalk.

Left—1 per cent sodium carbonate solution.
Right—N/20 sulphuric acid solution.

Left stalk—1 per cent iron sulphate solution.
Right stalk—1 per cent calcium chloride solution.

Fig. 5A. D 1135 plant cane six months old, Lower Aliona field. On left, first row of control cane, untreated. On right, first row of cane fertilized with sulphur. Sulphur applied before planting.

Fig. 5B. D 1135 plant cane six months old, Lower Aliona field. In foreground, control cane, untreated. In background, cane fertilized with sulphur applied before planting. The difference in color is plainly visible. The cane in the foreground is chlorotic, but there is little blighted-wilted-cane.

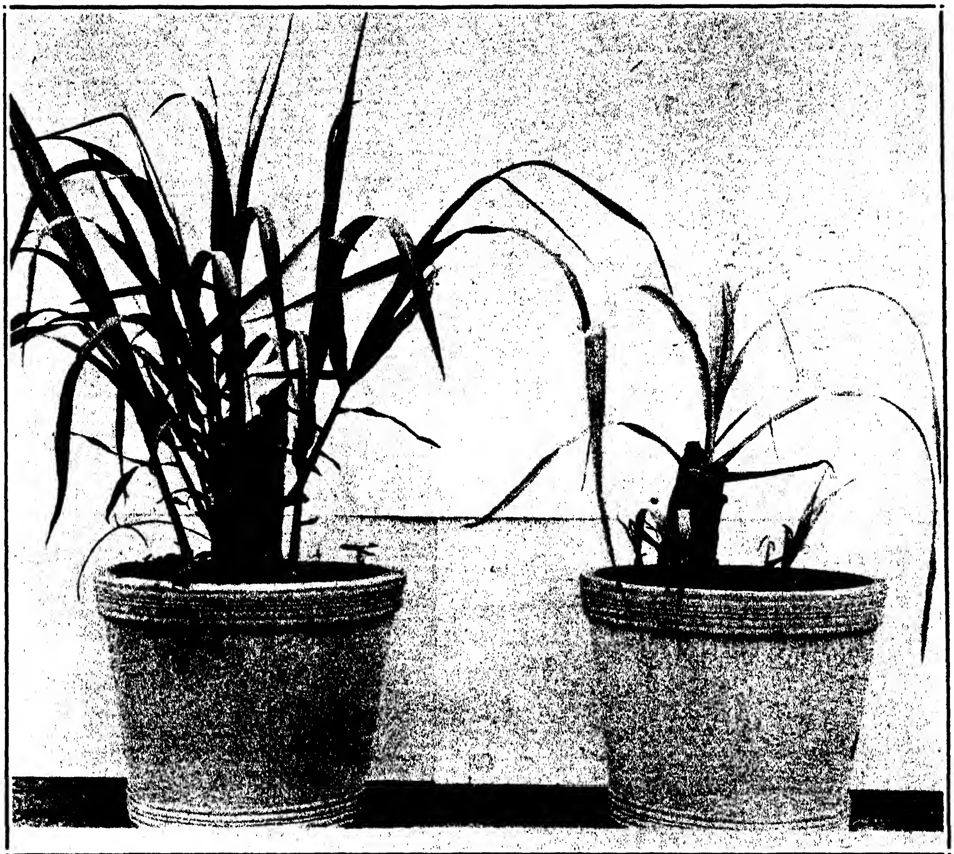

Fig. 6. Same plants as shown in Fig. 7. Left—fertilized with sulphur. Right—untreated control. Photograph taken at one month period after transplanting stumps. This being a closer view than Fig. 7, the difference in color is plainly visible, as is also the typical "damping off" on the smaller shoots.

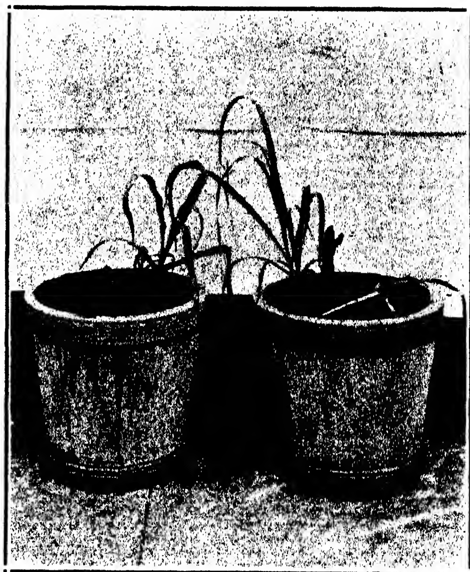

Fig. 7. Yellow Caledonia diseased stumps brought from Lower Aliona field, Pahala, and replanted in Lower Aliona soil at Experiment Station. All plants two months old. Left—Soils received sulphur, one ton per acre before planting, and plants entirely recovered. Right—Soils untreated—no recovery.

Fig. 8. Showing comparative root growth. Left—Two plants from sulphur pots. Center—1 received $Fe\ SO_4$ in the stalk; 2 received $H_2\ SO_4$ in the stalk. Right—Two plants from control—untreated pots.

Fig. 9. A.

Fig. 9. B.

Showing (upper) dry land rice and (lower) submerged rice. Pots from left to right: sulphur, sodium sulphate, sodium carbonate, ammonium sulphate, calcium carbonate, sodium chloride, sodium nitrate, calcium chloride, and check.

Sugar Prices

96° Centrifugals for the Period December 18, 1925, to March 9, 1926

Date	Per Pound	Per Ton	Remarks
Dec. 18, 1925	4.08¢	$81.60	Cubas.
" 21	4.11	82.20	Cubas.
" 23	4.14	82.80	Cubas.
" 30	4.195	83.90	Cubas, 4.18, 4.21.
" 31	4.21	84.20	Cubas.
Jan. 5, 1926	4.125	82.50	Cubas, 4.14, 4.11.
" 7	4.11	82.20	Cubas, 4.14; Porto Ricos, 4.08.
" 11	4.14	82.80	Cubas.
" 12	4.11	82.20	Cubas.
" 18	4.125	82.50	Cubas, 4.11, 4.14.
" 19	4.14	82.80	Cubas.
" 26	4.225	84.50	Porto Ricos, 4.21; Cubas, 4.24.
" 27	4.24	84.80	Cubas.
" 28	4.27	85.40	Cubas.
" 30	4.24	84.80	Cubas.
Feb. 4	4.27	85.40	Porto Ricos.
" 11	4.255	85.10	Cubas, 4.27; Porto Ricos, 4.24.
" 15	4.225	84.50	Cubas, 4.24, 4.21.
" 16	4.18	83.60	Porto Ricos.
" 23	4.14	82.80	Cubas.
March 2	4.095	81.90	Cubas, 4.11; Porto Ricos, 4.08.
" 3	4.08	81.60	Porto Ricos.
" 8	4.05	81.00	Porto Ricos.
" 9	4.02	80.40	Porto Ricos.

THE HAWAIIAN PLANTERS' RECORD

Volume XXX. JULY, 1926 Number 3

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Entomologists' Report on Termite Problem*

By F. Muir and O. H. Swezey

Termites have interested the Station entomologists from the foundation of the Station and observations on the species and their distribution have been made from time to time and published in the *Record* and in the *Proceedings of the Entomological Society*. Specimens have been in the Station collection for many years.

Their interest in this question was greatly increased in 1913 when a species of *Coptotermes* was first found in the Territory, as it belongs to a group which forms large nests in the ground and are most destructive on account of their numbers and fondness for wood. The genus *Coptotermes* also contains species which are known to attack living plants, sugar cane among others. At that time the entomologists pointed out that the presence of this insect in the Islands would alter the whole aspect of our termite problem and in time would place it in the forefront of the insect problems facing the Territory.

Mr. David Fullaway, of the Territorial Board of Agriculture and Forestry, undertook to investigate these insects and so the Station entomologists, while following his work and assisting in every way, have published very little on the subject.

Until recently the general public and, strange to say, the builders and architects have evinced slight interest in the subject in spite of the warnings of the entomologists, but the destruction in several large buildings and dwelling houses has recently brought the question more forcibly to their notice.

Recently some of the entomologists invited some of the lumbermen, architects and builders to meet at the Pan-Pacific Institute in Manoa and discuss the matter together, and this led to several recommendations regarding buildings and experiments to test the resistance of various woods and the effectiveness of preservatives. Another meeting is to be held very shortly to report progress.

We have two termites in the Territory of economic importance, *Cryptotermes piceatus* and *Coptotermes formosanus*.

* Prepared at request of the H. S. P. A. Trustees.

Cryptotermes Piceatus

This insect has been in the Territory for over twenty years, the first record being in 1904; before this date they were confused with *Kalotermes immigrans* under the name of *Kalotermes marginipennis;* the exact date of its introduction is therefore not known. The winged adults swarm at certain times of the year and the sexes mate. They then retire to a suitable place to start a new colony. A hole or crack in a piece of wood, or a small space between two pieces of wood, is a favorite location to start their home. The colony increases slowly and never becomes very numerous. This is the species found so frequently in houses, posts, fences and furniture. The attics are favorite places for them; they enter through the ventilators and the rough lumber of the rafters contains ideal nesting sites. Their presence is generally noticed by the small pellets of excrement looking like fine shot or rough, uniform sawdust.

We require more detailed knowledge of the distribution of this species. At present it is known all over Oahu, but it is likely to be distributed throughout the Islands.

On account of the smallness of the colonies the work of destruction is slow, although in time it is very thorough. Good paint together with absence of holes and crevices in woodwork is the best preventative. On rough wood, paint and preservatives are best applied by an air gun or air brush as the liquid then penetrates into holes, cracks and crevices much better than when applied by a brush. The ventilators of houses should be screened with insect proof wire.

Coptotermes Formosanus

This species swarms during certain times of the year in much larger numbers than the last mentioned. The newly mated couple find a place of refuge in the soil, in preference alongside a post or other woodwork in or on the ground. At first the female is active and attends to the eggs and young herself, but as the first generation grows up they take over this work and the female devotes herself entirely to laying eggs. A cell is excavated in the ground by the workers and the female remains therein, her abdomen increasing in size till it is larger than one's thumb. She is unable to move and is fed and attended to by the workers, the eggs being taken off by the workers and stored in other cells and attended to till they hatch. The fecundity of the female is colossal and she lives for several years. A colony once formed and the female having reached this condition, the numbers increase rapidly, and food in the shape of wood must be found to keep it going. In the search for food the workers tunnel through the ground for long distances. In an African species these tunnels have been followed for 300 yards. When dead wood is absent *Coptotermes formosanus* and *Coptotermes gestroi* (two very closely related species) will attack living plants.

An ordinary wooden building near a large nest can be damaged to a point of danger in less than a year.

The presence of this species can often be recognized by the mud-like cement with which they stop up holes and cracks in the wood they are working in.

So far the distribution of this species is throughout Honolulu and extending into the residential districts of the several valleys. Isolated occurrences have

been found at Oahu Sugar Company, one on the peninsula below Waipahu and one on the mauka side of the plantation just below the Waiahole ditch. It is also known at Kuhio wharf, Hilo, Hawaii.

There are four records of this species attacking living sugar cane. In 1917, on the peninsula at Oahu Sugar Company; in 1920, in Mr. Caum's garden, Makiki; November, 1924, in the mauka field of Oahu Sugar Company, and in March, 1924, at the Experiment Station grounds, Makiki. In all these cases termites were found attacking wood a short distance away.

There are two lines of attack against the damage done by these insects, first to protect our woodwork against attack, and second to kill off the nests.

The first is a mattter for the architects, builders and lumbermen, and economy will have to be a ruling factor. The use of metal to insulate buildings has been used successfully elsewhere. Wooden houses must be built on piles and these capped with metal discs and no woodwork from the building should be brought in contact with the piles or the ground. Brick, stone, cement, etc., houses can be insulated by a strip of metal about a foot or two feet above the ground, projecting for an inch or so on the outside. Concrete foundations are good if properly made and care is taken to seal up all holes caused by pipes, wires, etc., passing through. Lime cement is useless as the termites can pass through it as easily as through wood.

Paints and preservatives may be of help and several are being tried out and others have been sent for by Lewers & Cooke, Ltd., and other business men interested in the question.

The destruction of the nest is by fumigants and poisons. Arsenate has been found successful with some species. The success of insoluble poisons is chiefly due to the habit of termites to devour their own dead. Carbon bisulphide can be used to destroy nests, but its success depends upon the nature of the soil. Its economic use over large areas is questionable. Over small areas where it is desirable to erect a house it is very useful. The presence of termites in soil can be discovered by driving wooden posts into the ground and examining them a few months later. When termites are present then the spot can be fumigated with carbon bisulphide.

Termites as a Sugar Plantation Pest

These insects can affect plantations in two ways. First, by directly destroying sugar cane and secondly, by destroying woodwork, such as buildings, flumes, fences, ties, etc.

As a probable sugar cane pest the Station entomologists consider that the evidence at present available indicates that these insects will not play an important role. The four isolated cases recorded above all showed that the nests were in nearby woodwork. Similar isolated cases will happen, more frequently than in the past, but they are not likely to be of primary importance.

The reason for this conclusion is that in Formosa, Muir found that these insects did damage only in those regions recently cleared of forest trees and the old stumps allowed to remain. These stumps were all the sites of nests and in the dry season the termites attacked the surrounding sugar cane, most probably for moisture. A similar condition exists in the rubber plantations in Malaya

where *Coptotermes gestroi* attacks living rubber trees. *Coptotermes formosanus* have been present on the Station ground for a number of years and only on one occasion, when very large cane was growing under very favorable conditions, have they been known to attack cane. Over the greater portion of our plantations there is no woodwork of any kind, no dead stumps and seldom living trees, so there are few places for new colonies to start. Also the presence of our little common ant, *Pheidole megacephala,* in numbers in our cane fields is a good protection against the starting of new colonies.

As destroyers of property both species must be considered, and as *Coptotermes* gets established over larger areas precautions will have to be taken similar to what must now be taken in Honolulu. This is a problem which must be worked out by builders and entomologists together.

Biological Control

This question has been kept till the last as it is the most difficult to deal with. So far as we can see at present there is little hope along this line as we have so little information. Recently one of the Station entomologists was asked if he would recommend the Legislature to appropriate money to introduce parasites of termites into Hawaii and he replied: "No, for if he knew of any such he would ask the H. S. P. A. Trustees to send a man at once to procure them, and not wait for the Legislature."

In the tropics where these insects are numerous nearly every insectivorous animal will devour termites if they can get at them. In Java, a fungus is known to destroy whole nests. Nematode worms have been reported as destroying termites. It is possible that we might find something to work effectively in some part of the world, but the search will be long and success exceedingly uncertain.

Our own common ant (*Pheidole megacephala*) plays a very important part in checking the spread of termites. Nothing in the way of animal matter comes amiss to these ubiquitous little scavengers and termites form a dainty dish. Innumerable small colonies, before they can get well established deep in the soil, must be destroyed by them. In the mauka field of Oahu Sugar Company where termites were found eating living sugar cane some railway ties were found infested with small colonies. *Pheidole* were already found attacking these and a few weeks later when we examined the ties again the termites were all cleaned out by the ants.

Mr. Pemberton has been asked to make whatever observations he can on termites in the Malays.

Recommendations

It has been stated above that a meeting has already been held between the entomologists and others who are interested in this question, and another will be held shortly.

It would be good if a standing committee could be formed including a couple of entomologists, representatives of the lumber business, architects, builders and any others who are seriously affected by these insects. This committee could supervise and report upon such experiments, etc., as are recommended. Entomologists by themselves can do but little in this matter.

To acquire more information as to the distribution of these insects plantation carpenters can help by sending in specimens of woodwork attacked by them, along with specimens of the insects.

There is talk of asking the Board of Agriculture and Forestry or the next Legislature to pass a rule or law prohibiting the movement of wood attacked by termites. This idea should be discouraged for the following reasons:

Prohibitory laws always breed resentment and unless distinct good can come of them they should not be enacted. *Cryptotermes* has been with us for over twenty years and as it can be taken about in furniture, packing cases, matting and many other things as well as building lumber it must be widely distributed by now and a prohibition on the movement of old building lumber and not on other means of distribution would be illogical. It is much better to educate builders, and others, to the danger of using such lumber in reconstruction or building. The habit of *Coptotermes* nesting in the ground makes the probabilities of specimens ready to form nests being carried in lumber fairly remote. There is as much chance of conveying a young nest in a potted plant or in a roll of matting.

But, should the inhabitants on Kauai, Maui, Molokai, etc., where these two termites are not known to be at present, consider that they should be protected, then regulations might be passed covering this feature, although such regulations will be more psychological than materially effective. When these insects are known to be on these other islands then the regulation should be repealed.

Although the Station entomologists have published very little on this subject they have never lost sight of it. It has been discussed on many occasions by the Hawaiian Entomological Society and its importance is thoroughly recognized by all entomologists in the Territory.

Termites, or White Ants, in Hawaii

Considered from the Plantation Standpoint

By David T. Fullaway

Entomologist, Board of Agriculture and Forestry

Introduction

The damage to wood, woodwork and wood products caused by termites or white ants has been increasing noticeably from year to year in the city of Honolulu, and the losses that have been experienced thus far, amounting to hundreds of thousands of dollars, and those that are almost certain to occur with the passage of time, give occasion for serious thought.

Termites are not new insects here. As early as 1883 two species were known[1]. One of them was later said to have done great damage to wooden buildings in the city of Honolulu[2].

The extraordinary increase of wood destruction is due to the entrance at Honolulu of two additional species[3], one vastly more prolific than the precedent

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1 *Neotermes connexus* and *Kalotermes immigrans*.
2 F. H., ii (2), p. 88, and Intr., p. clxxiv.
3 *Coptotermes intrudens* and *Cryptotermes piceatus*.

species, the other better adapted to conditions here. They are presumed to have come in oriental commerce not long before or after 1900. These species in the quarter century supposed to be here, have spread and completely occupied the city of Honolulu. They have also occasionally been found in isolated communities elsewhere[4], notably in Hilo. These species will be referred to in this account as the soil-nesting termite and the dry-wood inhabiting termite.

Nature of the Termite

Termites are social insects, living in communities of larger or smaller size. The location or home of the community is usually referred to as a nest or a termitarium. Individual members of the community are only in the smallest

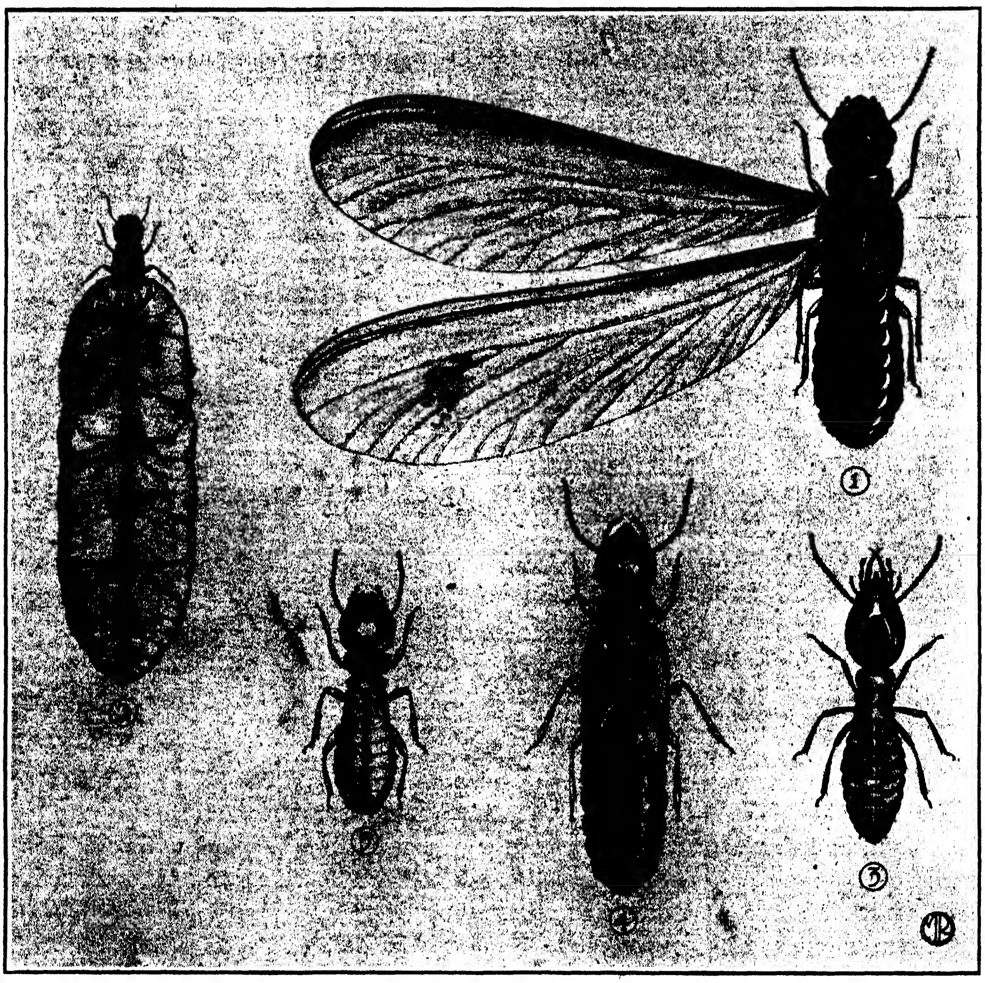


Fig. 1. Illustrating the Soil-nesting Termite (*Coptotermes intrudens*). 1—Winged adult; 2—Queen; 3—Soldier; 4—Nymph of winged form; 5—Worker (x ca. 7 except 2 which is x 2). (Original.)

[4] Hilo and Oahu Sugar Co. Plantation, mauka and makai lands.

degree independent. The biological unit in these insects is not the individual but the society, and their ways are better understood with this fact in mind. The development of social life among the insects has led to a division of the labor of the society and the rise of castes among the individuals. The termite community usually consists of a queen, soldiers and workers. Young or immature forms as well. The queen produces eggs, which become fertilized in passing from her body; they are extruded on to the floor of the nest and hatch after the lapse of a few days. The young thus emerging are at first undifferentiated larvae, but later develop characteristic marks and eventually become adults, either winged or wingless. The wingless forms are the soldiers and the workers which never develop sexually and are hence said to be sterile. The winged forms, on the other hand, are fully developed male and female adults and are sometimes referred to as the fertile or sexed forms. These latter occur in large numbers at certain times and after a preliminary period of inactivity in the termitarium, leave in a body or swarm, indulge in a nuptial flight, pair, drop their wings, and if able, engage in the foundation of a new community, the male impregnating the female,

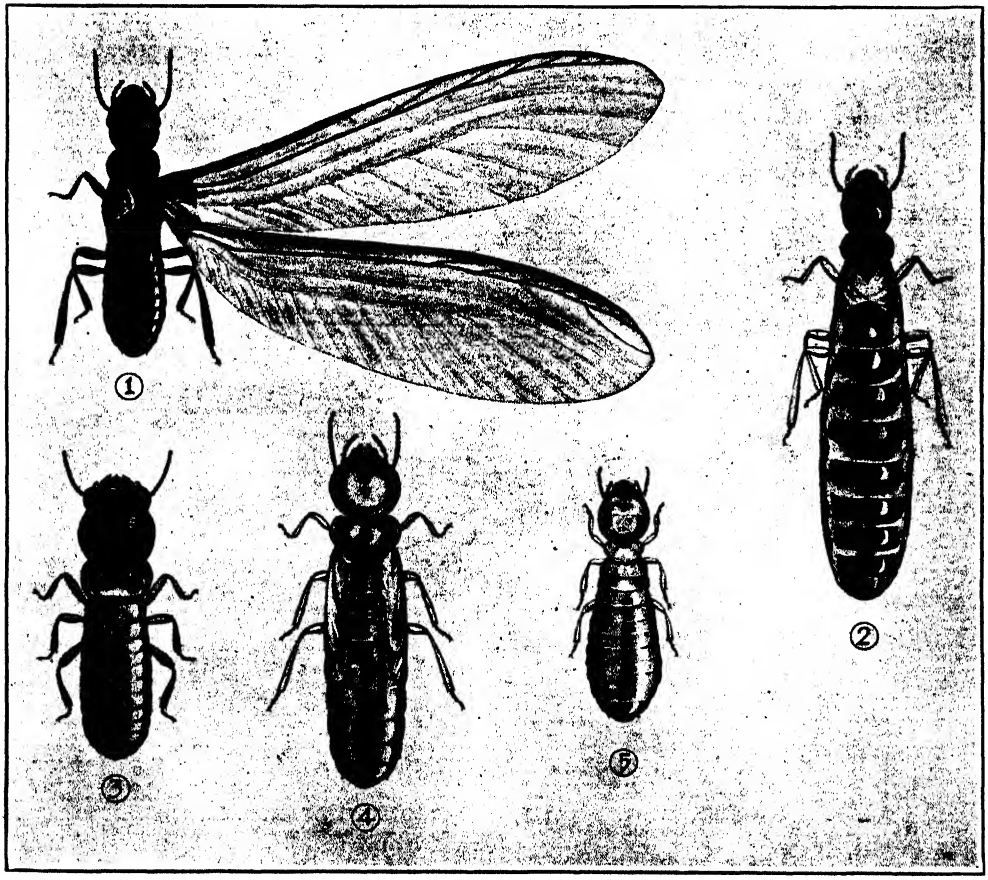


Fig. 2. Illustrating the Dry-Wood Inhabiting Termite (*Cryptotermes piceatus*). 1—Winged adult; 2—Queen; 3—Soldier; 4—Nymph of winged form; 5—Young nymph (x ca. 7). (Original.)

which then develops into a queen. Until the first workers are produced, the male and female must provide for themselves and young, but later the workers do everything, except in the special fields of reproduction and defense, which are the respective functions of the king and queen and the soldiers. The nuptial flight may occur at any time of the year, but the largest emergence of winged forms is in the spring. The flights occur just after dark in Hawaii. This is the critical moment in the termite's life, for thousands of pairs perish where one succeeds in finding shelter and protection from enemies. Termites shun light; exposure to the sun's rays is inimical to them and if long continued proves fatal. They are easy prey to the black ant when their excavations or galleries are broken into and exposed, for their bodies are soft and easily pierced by the powerful jaws of the ant.

Peculiarities of the Soil-Nesting Termite

The soil-nesting termite is apparently hypersensitive to a dry atmosphere and depends on the soil moisture to obtain suitable humidity in its galleries. When it works above the natural level of the soil it often corrects a lowered humidity by carrying soil particles from below into the aerial ramifications of its galleries. This peculiar moisture requirement of the soil-nesting termite is undoubtedly a handicap which has retarded its progress here considerably. On the other hand, its spread has been greatly facilitated by the continuous line of wooden poles used for supporting electrical conductors, all of which have their butts buried in the ground and otherwise give shelter and protection to the colonizers of the soil-nesting species. This species undoubtedly got a foothold here somewhere along the waterfront and spread gradually along the thoroughfares of the city

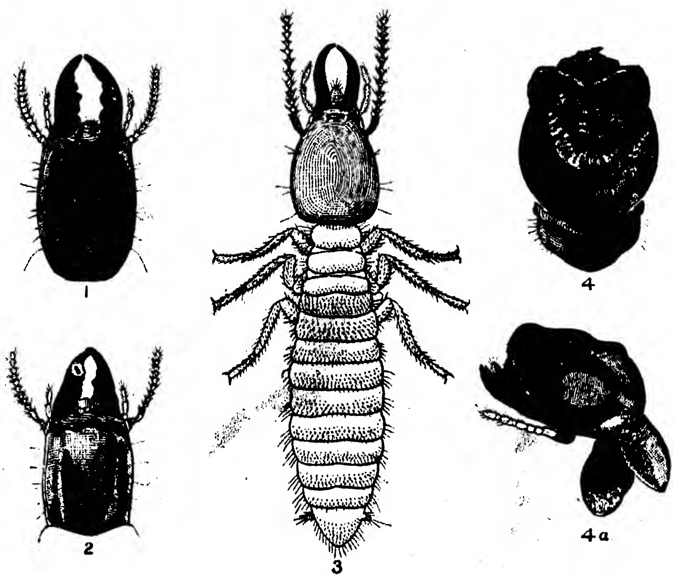


Fig. 3. Illustrating the Soldier form of Hawaiian Termites. 1—Head of *Neotermes connexus* x 5; 2—Head of *Kalotermes immigrans* x 5; 3—*Coptotermes intrudens* x 9; 4—Head of *Cryptotermes piceatus* x 11; 4a—Same, lateral view. (The Hawaiian Forester and Agriculturist, Vol. XVII, No. 10, Plate I, opposite p. 296.)

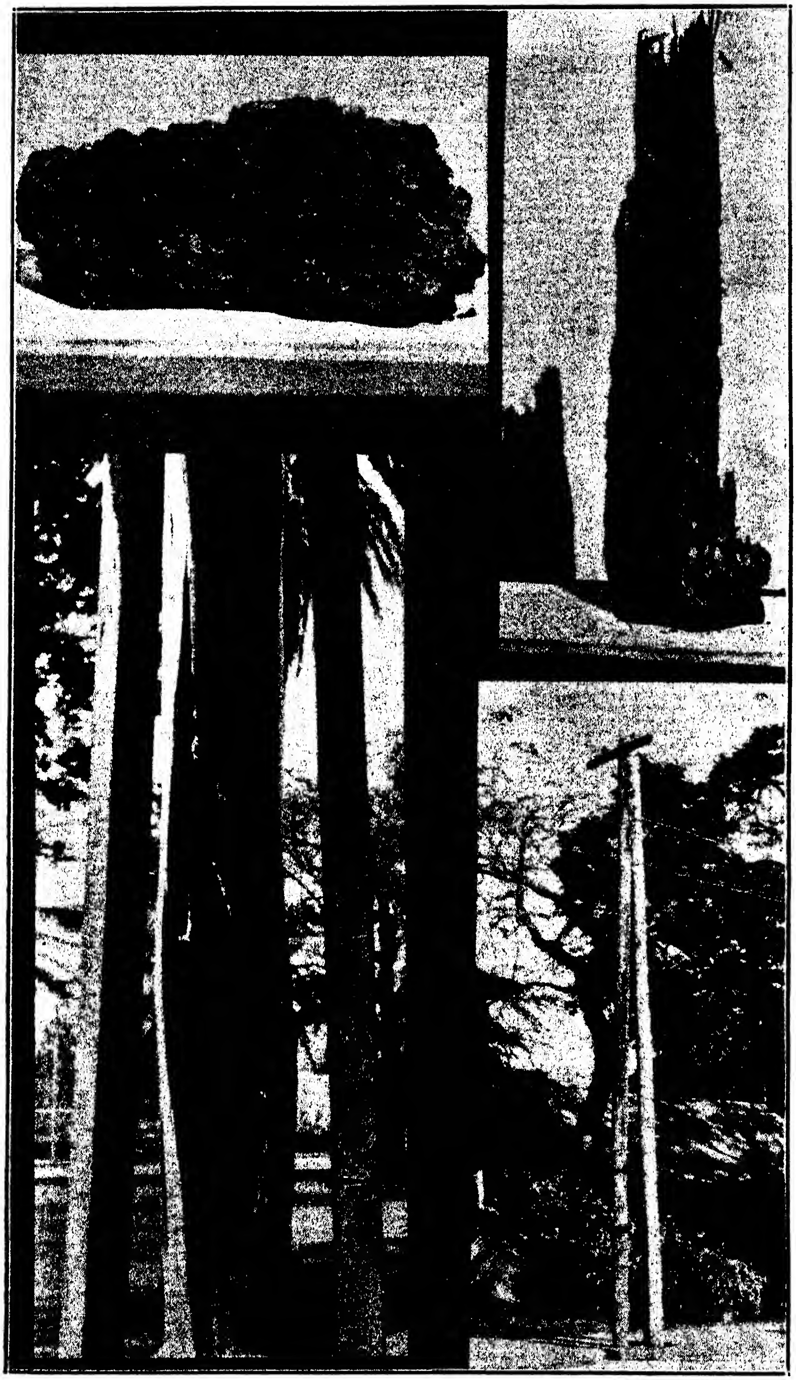


Fig. 4. Illustrating the destructive work of the soil-nesting termite (*Coptotermes intrudens*). Upper left—Portion of the termitarium composed of earth, excrement and saliva; Upper right—Section of damaged timber showing hollow core; Lower left—Supporting column in former Capitol bandstand ruined by this species; Lower right—Telephone pole damaged by it (reduced). (Original.)

by means of the poles. Occasionally a fence post or building would be invaded, but these occurrences are isolated ones and lack the continuity of the pole infestations. As the spread of the soil-nesting species has been outward and gradual it is reasonable to assume, and the facts appear to bear out the assumption, that the down-town sections are the most densely populated, the communities becoming less numerous and populous away from the center.

The significant feature in the biology of the soil-nesting species is the large size the communities are able to reach. Two to three hundred thousand is a low estimate of the number of individuals disclosed in breaking into an average-sized termitarium. In the establishment of a community, progress is slow at the beginning, but after the first year the community grows very rapidly. It is enabled to do so by a remarkable secondary or late-in-life growth which takes place in the queen, probably stimulated by the development of the sexual organs subsequent to coitus. The queen thus attains relatively enormous dimensions (one inch or more in length), but the increase in size only directly affects the abdomen, as it is due mainly to the increased development of the ovaries and fat body. Egg production increases at the same time and it is no exaggeration to say that at the height of its powers one of these queens lays from 500 to 1,000 eggs a day. With a daily increment such as this over a long period, it is no wonder that these communities become so populous and devastating.

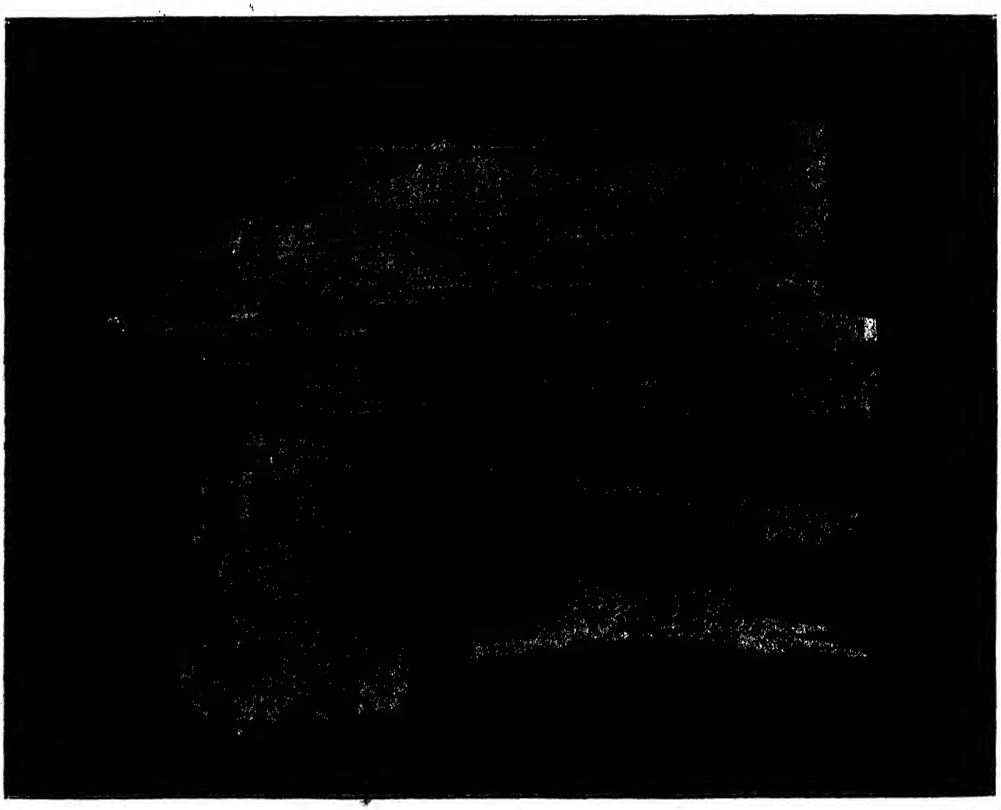


Fig. 5. Illustrating the destructive work of the soil-nesting termite (*Coptotermes intrudens*). Interior portion of damaged timbers exhibiting the replacement of cellulose by a composite of earth, excrement and saliva which has scarcely any tensile strength. (Reduced). (Original.)

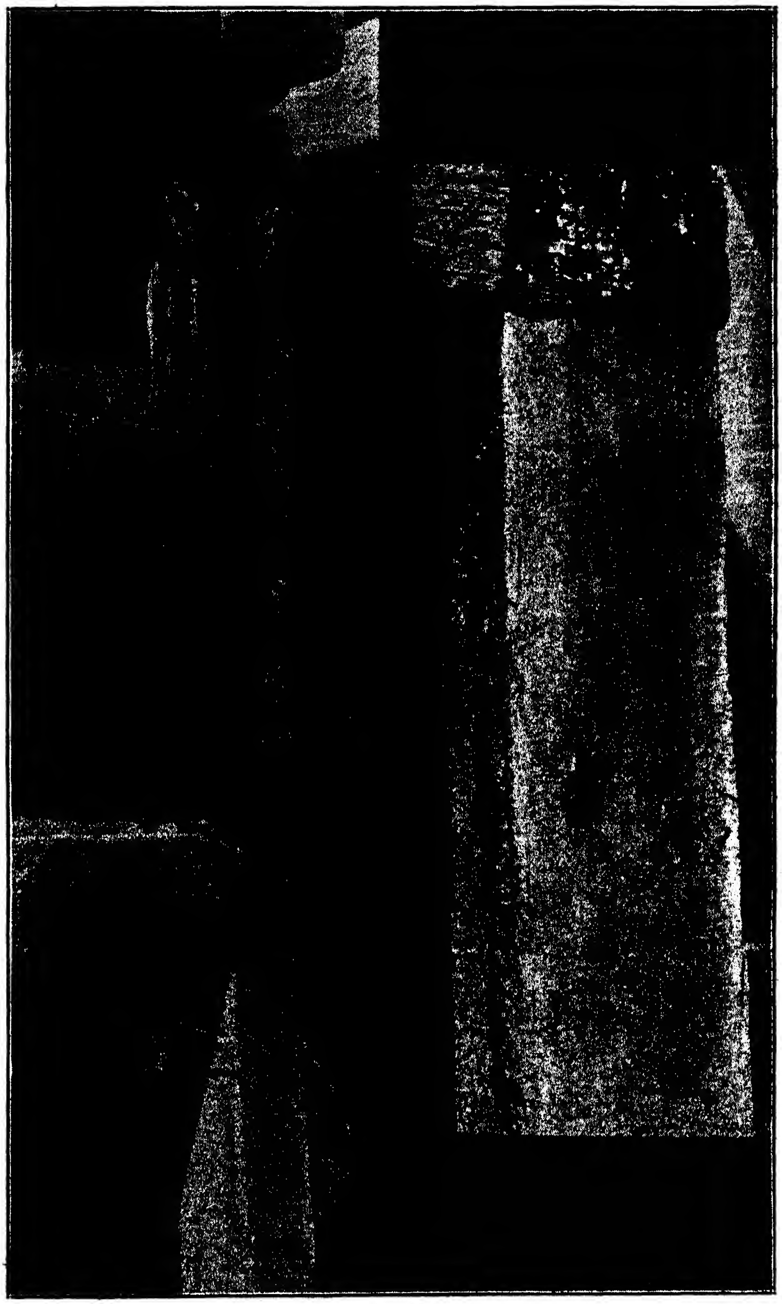


Fig. 6. Illustrating the work of the soil-nesting termite (*Coptotermes intrudens*). Runway constructed on supporting-timber and leading from underground nest to frame-work of dwelling-house in Honolulu. (Reduced.) (Original.)

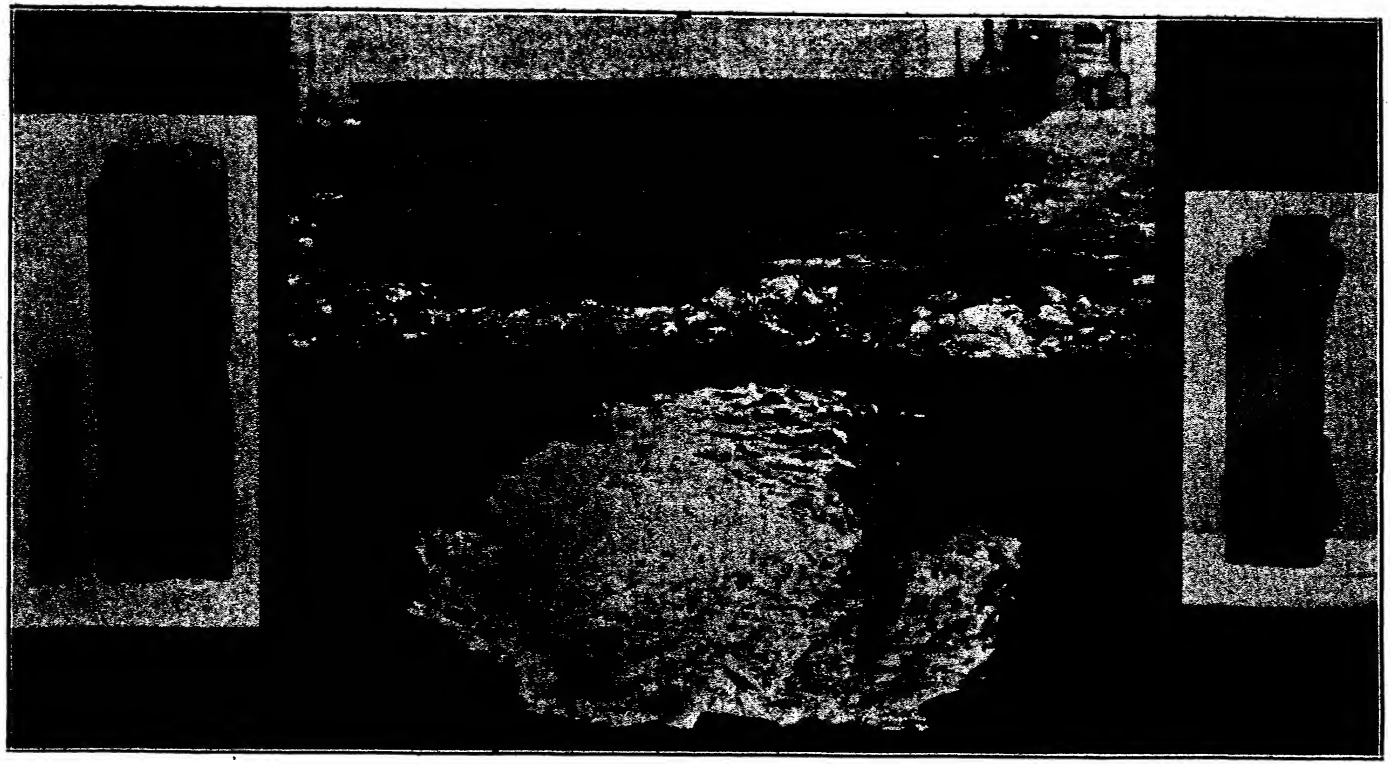


Fig. 7. Illustrating the destructive work of the three lowland species of termites in Hawaii. Center, that of the soil-nesting termite (*Coptotermes intrudens*) damaged railroad ties above, interior portion of damaged timber—a termitarium—below; Left, that of *Kalotermes immigrans*—a damaged timber; Right, that of *Cryptotermes piceatus*—an infested wood sample. (Reduced.) (Original.)

Foraging is often necessary in rapidly expanding communities and quite frequently run-ways are discovered which cannot be traced to a nest owing to the friable nature of the soil through which they extend or to a devious passage through rock, concrete, etc., which appears to be impervious but really is not. When obliged to run on an exposed surface, as they are sometimes between crevices, a covering of earth or fecal matter is constructed to protect them from the light and sundry enemies and at the same time preserve the correct circumambient humidity. The discovery of such covered run-ways generally leads to the unmasking of an extensive infestation.

The soldier of the soil-nesting termite has a yellowish brown head and sickle-shaped mandibles; it is quite ferocious, and emits an acrid whitish fluid from the front of the head when disturbed. All the forms appear to be a trifle larger than the corresponding forms of the dry-wood inhabiting termite, and a trifle hairier. The wing venation of the adult sexed form is, of course, quite distinct.

Peculiarities of the Dry-Wood Inhabiting Termite

The dry-wood inhabiting termite is principally a house-infesting species. It is found in the frames of the house and to some extent also in the supports. It likewise infests floors and ceilings, mouldings, picture frames, furniture of all kinds and wood products generally. The communities of this species are quite small, averaging about 100 individuals; but on account of the adaptability of the species to dry wood, which is used so extensively here for dwellings, and the ease with which new communities are initiated, it is a very close second to the soil-nesting termite in destructiveness.

The nest of this species is very simple. A slightly widened gallery in the dry wood serves the purpose. The queen never reaches very large size and produces relatively few eggs. The communities are established in the usual way by a mated pair of sexed adults which have, subsequent to the nuptial flight, found shelter and protection from enemies, dropped their wings and settled down to work. The infestation of wood with this species, however, is always direct, as the nest is in the wood and the communities are not so populous that foraging must be resorted to. Access is obtained by a boring of 1 mm. diameter. Once inside, the boring is enlarged somewhat and the excavation of galleries is begun. These are extended lengthwise, that is, with the grain of the wood, and widened in places. Short galleries, connected by borings, are the rule rather than one long continuous excavation of a uniform cross section.

The castings of this species are quite characteristic, consisting of tiny compressed pellets, and as they are occasionally ejected from the nest or excavation through a boring, falling in a heap or scattered mass directly below the point of ejection, an indication is given of the presence of this termite in the wood. All borings and excavations opening externally are soon closed with a characteristic chocolate-colored, parchment-like curtain.

The soldier of the dry-wood inhabiting termite is quite distinct in appearance. The head is large, thick, excavated in front, and characteristically sculptured on top, generally black. The winged forms are small, with narrow wings, which have a characteristic venation. It is not known where the dry-wood inhabiting

Fig. 8. Illustrating the destructive work of the soil-nesting termite (*Coptotermes intrudens*)—Supporting timber of a large tenement in Honolulu, so badly damaged by this species that the structure collapsed in the severe wind storm of December, 1918. (Reduced.) (Original.)

termite got a foothold here, but it is widely distributed and most thoroughly established everywhere. There is hardly a house in Honolulu which they have not infested.

The Termite Problem as It Affects the Plantation

The termite problem is acute today in Honolulu and in a smaller way in Hilo. It affects principally the holders of improved property. Public service corporations, dealers in goods subject to attack and the government are also concerned. It is no problem for the plantations at present, but what about the future? Unquestionably these two new and extraordinarily destructive species, which are now confined to the cities, will eventually spread into the country, and isolated communities will be established in suitable spots. It is questionable that they will be able to do the damage to cane here that they do in other cane-producing countries where the environmental conditions are more favorable. However, no pains should be spared to destroy nests as they occur on plantations. Likewise suitable measure should be taken to prevent their access, as far as possible. In time it is possible that plantation mill sites, residential quarters, warehouses, villages and camps will furnish locations for termite activities. A problem will then exist for the manager similar to that confronting the city property-owners today. The following suggestions are offered:

Watch carefully for the appearance of both species in the settlement as well as in the field. Act promptly to eradicate an infestation. Carbon bisulphide can be used against the soil-nesting species after the nest has been located. It is applied as a soil-fumigant through a piece of one-inch pipe into a hole a foot deep directly over the supposed site of the nest. The hole should be filled with dirt after pouring in the carbon bisulphide and the ground tamped.

Do not anticipate the natural spread of the dry-wood inhabiting termite by bringing second-hand lumber to the plantation from the city and thus introducing it. Such lumber is almost certain to be infested and is known to be capable of carrying this particular species into a new locality.

All alterations and repairs to old buildings and all new building should be planned and carried out with the termite menace in mind. The day of attack can thus be anticipated and damage and loss prevented.

For instance:

Inasmuch as termites live almost exclusively on wood, the substitution of other material will give the greatest measure of relief from their attacks.

On the other hand, it has been proved possible to isolate the woodwork of a building from the soil-nesting termite by the use of a concrete slab between the ground and the wood, with proper attention to detail in the formation of the slab and the arrangement of connections above and below. The slab should be moderately thick (6 in.) and well reinforced. The concrete mixture should be especially good, and care should be taken in the laying and drying to avoid cracks, pores, etc. The problem of ground settlement should be taken into consideration. A finish of cement on the upper surface of the concrete slab will serve to fill indistinguishable crevices.

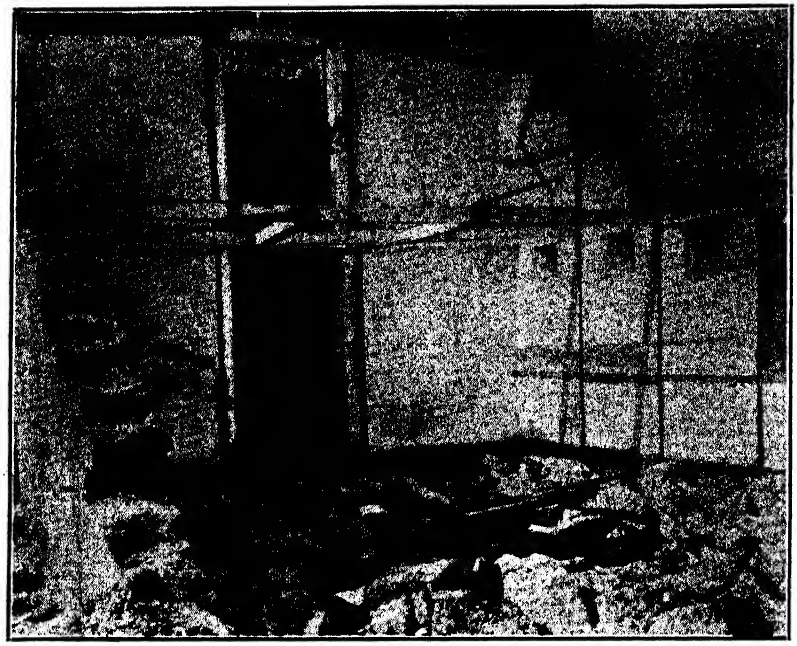


Fig. 9. Illustrating the destructive work of the dry-wood inhabiting termites (*Kalotermes immigrans* and *Cryptotermes piceatus*)—Damaged timbers in former county jail, Honolulu. (Original.)

The further removed the woodwork is from the ground the better, as opportunity is thus given to observe the run-ways of possible invaders.

It is possible to protect the upper portion of a building from infestation of termites moving along run-ways when use is made of a thin metal cap on all foundation walls and piers, the cap projecting about one inch beyond the vertical surface and having the edges turned down sharply. This device is extensively used in Australia and protects the buildings from sudden attack, anyway. The guards need some watching, however.

The same protection can be secured in cheaper buildings by raising the building off the ground, using solid concrete piers 4 or 5 feet in height as supports, with termite guards on top. Or more simply, a 4 in. concrete cube with termite guard on top, can be inserted under all present underpinnings. At the same time, however, steps must be isolated from the building or placed on a concrete slab with termite guard. Likewise all screens enclosing basement areas, vine trellises, etc., must be removed away from the building, and they should preferably be constructed of metal lath; if made of wood, they should be underlaid with a concrete slab having termite guard at the top. If these suggestions are followed the building would be reasonably safe.

Some measure of protection will follow the treatment of wooden supports with such ant repellants as creosote, crude oil and kerosene or carbolineum. Treatment of the ground with the same materials, using them at the rate of 1 gallon to every 6 square feet, is also recommended as a protection to the building.

Fig. 10. Illustrating the destructive work of the dry-wood inhabiting termites (*Kalotermes immigrans* and *Cryptotermes piceatus*)—Damaged woodwork of dwelling-house in Kakaako. (Original.)

All the above measures anticipate the eventual appearance of the soil-nesting termite on the plantations. When infestations actually occur, the nest should be sought first, naturally, and a charge of 8 oz. of carbon bisulphide put into the ground over it to kill the queen.

Protection against the dry-wood inhabiting termite must be sought in a different way, as this species infests wood directly. Perhaps the greatest protection will be obtained by treatment of the wood. An entirely satisfactory treatment to make wood termite-proof has not yet been discovered. Creosote is perhaps the best preservative, but it cannot be used on interior finish, furniture or other wood products of common use, on account of the so-called "bleeding" which follows and the resulting inability to paint over it with satisfactory paints. Corrosive sublimate and zinc chloride are good preservatives and particularly suitable for interior finish but are not considered generally useful on account of the danger of poisoning as a result of their use. Corrosive sublimate, phenol, alcohol and shellac (corrosive sublimate 50 gms., phenol 50 gms., alcohol 2 liters, liquid shellac 4 oz.) make a good mixture, and the danger of poisoning just mentioned is in this case obviated by the shellac.

Resistent timbers, of which there are a few, would be useful, but they are difficult to obtain and expensive.

There is no question about the value of a good heavy coat of paint as a preservative.

The thorough screening of houses particularly of attics, will help materially in reducing the incidence of infestation. Infested attics can be treated with a mixture of crude oil and kerosene 50-50, care being taken, by laying newspapers, to prevent the drip going through the ceiling.

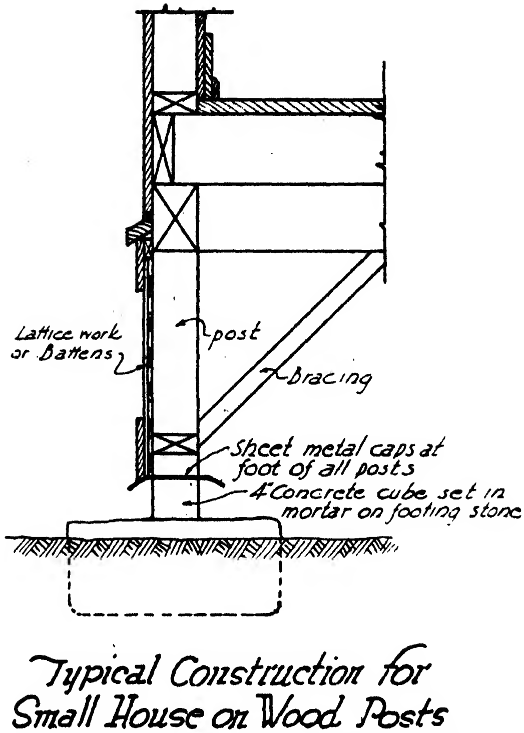


Fig. 11. Illustrating a method of termite-proofing a wooden building. (Original.)

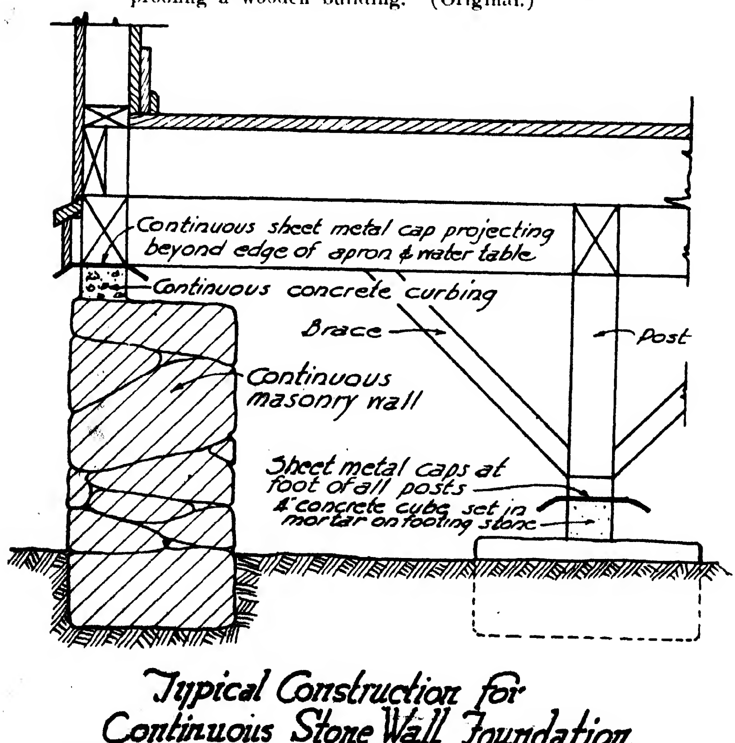


Fig. 12. Illustrating a method of termite-proofing a wooden building. (Original.)

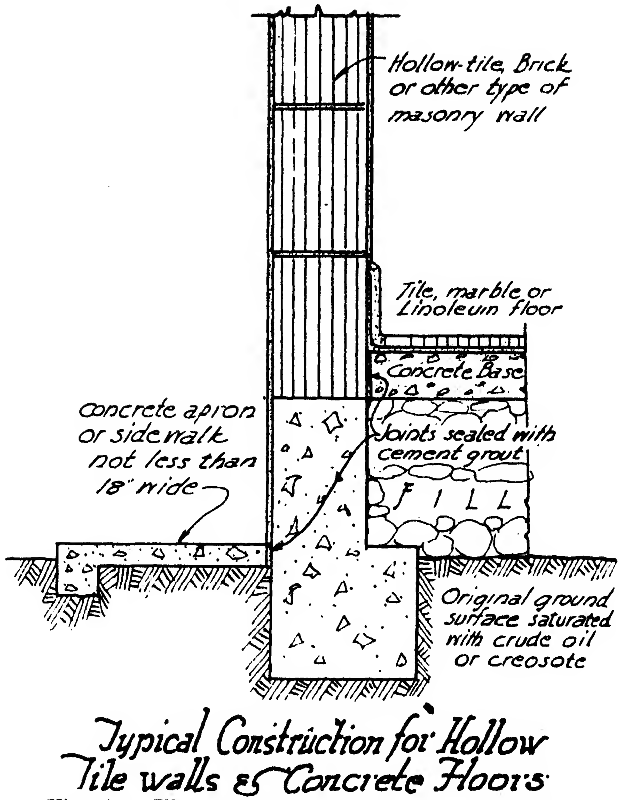


Fig. 13. Illustrating a method of termite-proofing a building. (Original.)

Trapping the winged forms flying inside a building by turning off all the lights in a room save one, and placing a white wash-bowl underneath, filled with water, is also a commendable practice.

Furniture and other wood products infested with dry-wood inhabiting termites can be fumigated with carbon bisulphide in a fumigating vault or chamber to rid them of infestation. Another method of accomplishing the same result is to expose the objects to strong sunlight for five or six hours.

Exotic Trees in Hawaii

By H. L. Lyon

Melaleuca leucadendron: This promising tree which has come to us from Australia is known in its native land under the following names: Paper-bark tree, White Tea-tree, Broad-leaved Tea-tree, Swamp Tea-tree, Cajeput-oil tree, Nectar tree, Gelam tree, Atchoourgoo, Bethar, Bichuma, Kyenbooree, Morngi, Numbah, Oodgeroo.

We consider "Paper-bark tree" the most appropriate name for its designation in Hawaii and hope that this name will be adopted here in preference to the others.

The most striking feature of this tree is its white bark, which is composed of innumerable, superimposed layers that can be peeled off like sheets of paper. In this respect, it resembles the well-known paper birch of North America. *Melaleuca leucadendron* is much more prolific in the production of paper bark than is the paper birch, however, for young trees in our cultures only 2½ inches in diameter had developed bark fully ½ inch thick, while trees 6 and more inches in diameter possessed bark well over an inch thick. This excessive padding of the trunk with lifeless bark enables these trees to withstand the heat of grass and brush fires. Only the outer, loose layers burn or char and the heat never reaches the living tissues which lie next the wood. It seems that grass and brush fires often run through groves of these trees in Australia, and Maiden (1:91) holds that these circumstances are responsible for the rather contradictory scientific name which was applied to this tree, for he explains as follows:

Melaleuca. From two Greek words *melas*, black, and *leukos*, white, because the trunk of the first tree described was black and the branches white. The explanation probably is that trunk and branches were alike papery and white, but that the trunk (as is often the case) was charred by a fire, giving it a blackish appearance.

The paper-bark tree is said to range from Queensland in Australia north through the Malay Archipelago to Burma. Australian botanists tell us that it is a very variable species and they recognize several well-defined varieties within the confines of their own country. These varieties range from shrubs or small trees with rigid, erect branches to tall trees with slender branches which are often drooping. Maiden (1:96) describes it as a tree "up to 40 or 50 feet, and a diameter of 1 or 2 feet in central and coastal New South Wales, but attaining a large size as Queensland is approached," and Baron Von Mueller (181) writes, "This tree attains a height of 80 feet, with a stem up to 4 feet in diameter." Its natural habitat in Australia is said to be along the coast in moist, sandy localities. It is very tolerant of salt and Von Mueller recommends it for planting "in salt swamps where no eucalyptus will live."

The paper-bark tree affords products of considerable value to man. The Cajeput oil of the pharmacists is obtained through distillation of the leaves and young twigs. The pronounced insulating properties of its bark render this of commercial value and large quantities are now being shipped to Europe from the Orient to be used as insulating material about refrigerators and steam pipes. The wood has merits that should make it especially attractive to us here in Hawaii if it really has the properties claimed for it by the authorities quoted below:

The wood is fissile, hard, close-grained, regarded as almost imperishable underground, and resists the attacks of the termites. It is well adapted for posts, wharf-piles, ship-building, and various artizans' work.—Baron Von Mueller, pg. 181.

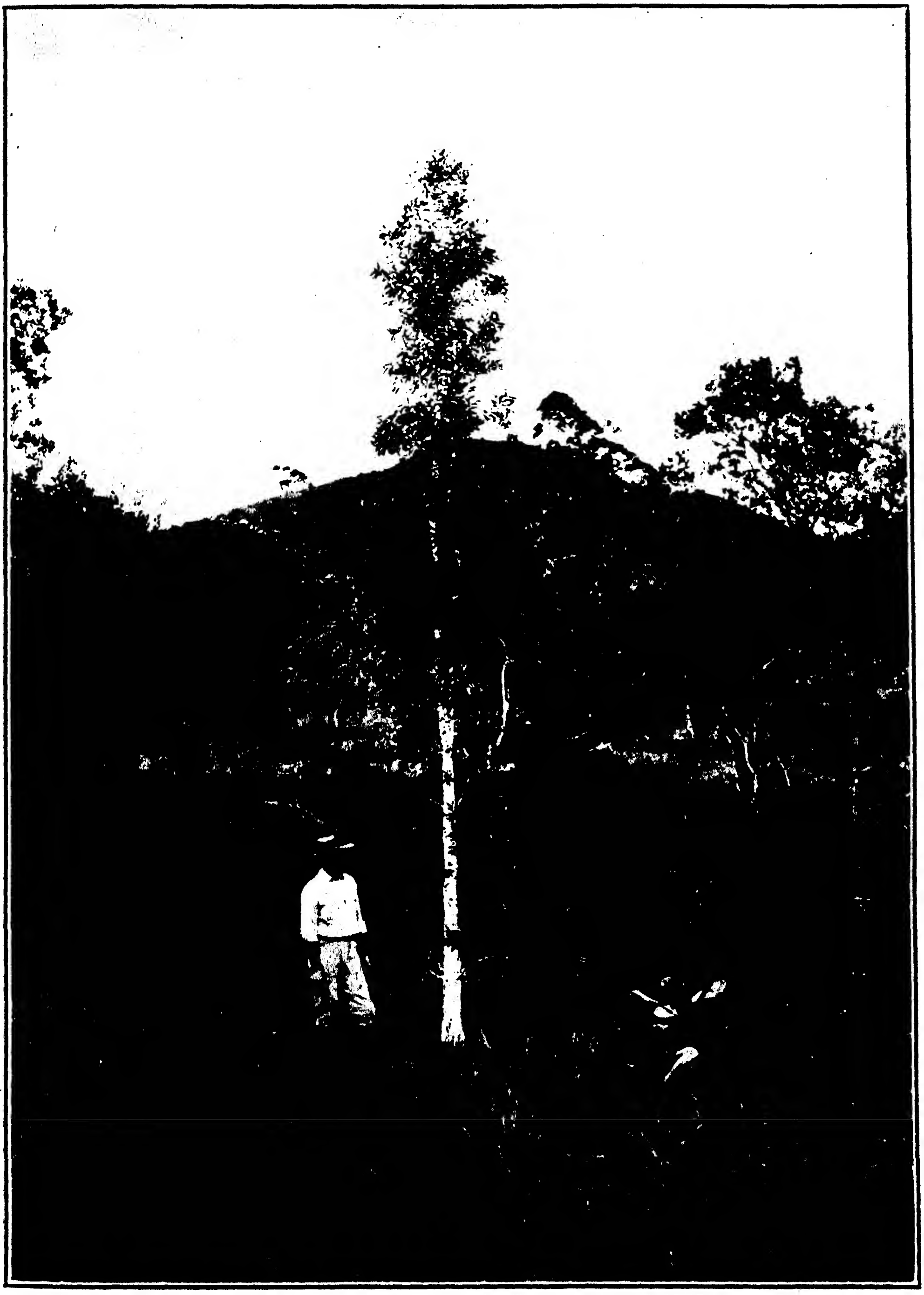
Wood of a pinkish colour, hard and close-grained, very valuable for underground work and wharf piles.—F. M. Bailey, pg. 67.

When worked, this timber smells like Brazil nuts. A close-grained, hard and durable wood. Brownish red in colour.—Wren Winn, pg. 19.

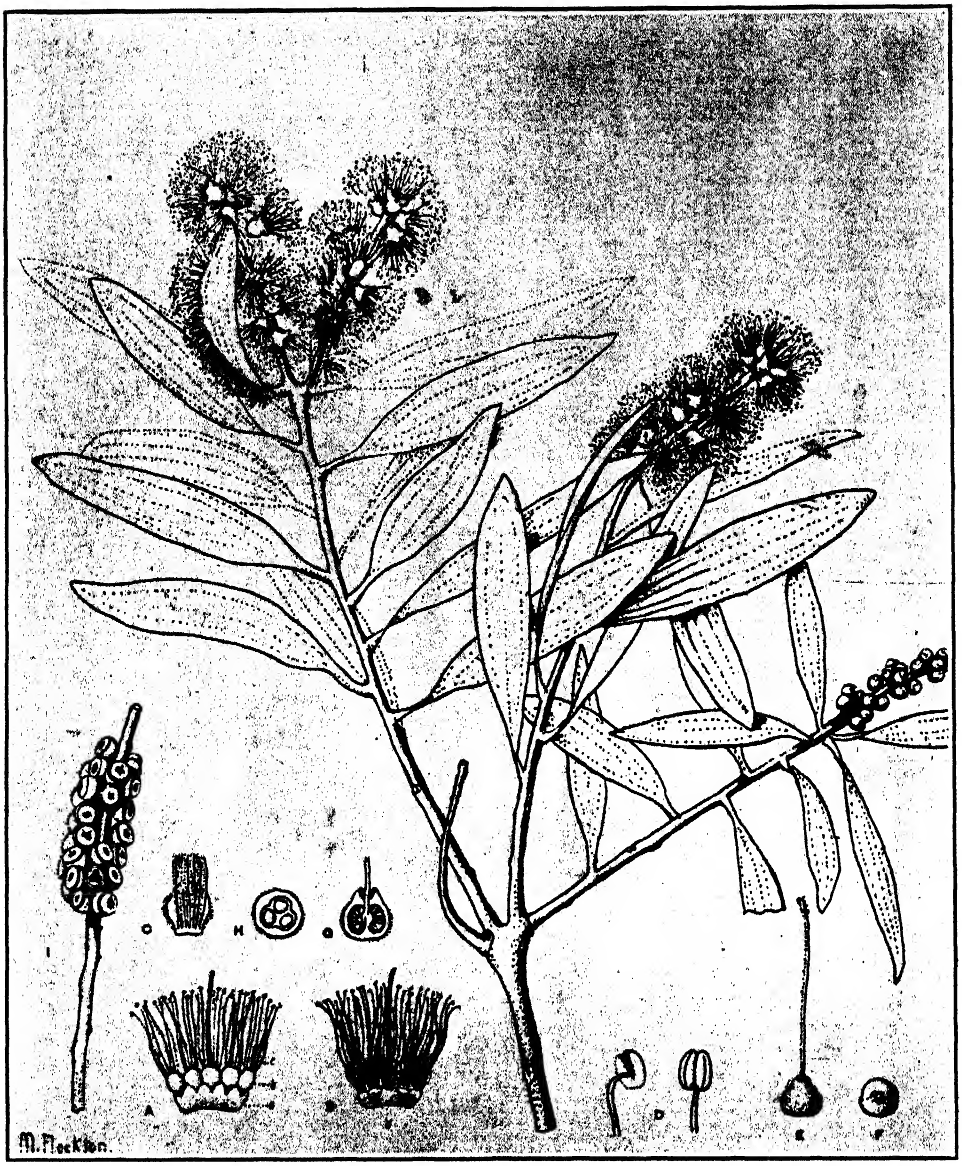
Melaleuca leucadendron, the White tea-tree, is an extremely pretty wood, with ripple markings and extremely durable in the ground.—Laslett and Ward, pg. 255.

Durable, cross-grained, . . . lasts well underground, resists white ants.—Ednie-Brown, pg. 28.

Excellent for fencing-posts in damp situations, being almost imperishable underground. —Nilson, pg. 5.



A paper bark tree growing in a forest planting above Wahiawa at about 1,100 feet elevation. At the time this picture was taken, the tree had been in the ground three and one-half years.



An illustration copied from Maiden's Forest Flora of New South Wales, showing botanical character of paper bark tree: *A*—Outside view of the flower opened out. *a*—Calyx. *b*—Petals. *c*—Stamens. *B*—Inside view of the flower opened out. *d*—Pistil. *C*—One staminal bundle with a petal. *D*—Stamens. *E*—Pistil. *F*—Ovary, showing convex summit. *G*—Vertical section of ovary. *H*—Cross section of ovary. *I*—Twig bearing fruits.

Burns well with a short, lively flame; heat expels resin; . . . *Grain.* Fine to medium, open; sometimes very sinuous, at others straight.—Herbert Stone, pg. 132-33.

Exceedingly hard and cross-grained, almost imperishable in moist places, but otherwise not of special merit; greatly used for ship timbers, boat knees and posts; wood much resembling that of the Melaleucas generally, very apt to crack and fly open on drying.—Maiden, 1:96.

The paper-bark tree was undoubtedly introduced into Hawaii many years ago, for there are now a few large trees to be found in widely separated localities. Apparently, it has never been planted extensively for all of the trees which we have thus far encountered occur in small groups or as isolated specimens. So far as we are able to judge, the trees now growing here are all derived from Australian stock, although they do not all display exactly the same characteristics. In its best form, it is an upright-growing tree with a straight trunk and a rather narrow crown. Most of our trees approximate this type.

A number of fruiting paper-bark trees are to be found in the forest plantings of the Board of Agriculture and Forestry in Manoa Valley. A few excellent specimens are growing near Mr. von Holt's mountain house at Palehua in the Waianae Mountains. Several trees have been planted along the roads leading to Kuhio wharf in Hilo and young plants may be found on the nearly naked lava in their vicinity which have grown from self-sown seed. Some of the largest and best specimens in the Islands occur on low land near the shores of Nawiliwili bay on Kauai. Mr. G. N. Wilcox owns the property on which they stand, and is, no doubt, responsible for their planting.

In December, 1919, we gathered seed of *Melaleuca leucadendron* from a tree in the Plant Introduction Garden in Miami, Florida, and the first lot of paper-bark trees reared at our nursery were grown from this seed. These trees were planted out in a great variety of situations and have done remarkably well, producing trees of good form. Some of them bore ripe seed when only four years old. Most encouraging results have been obtained with these trees in the thin, wet soil on flat-topped ridges where the native trees fail first and few exotic trees will grow. It would thus appear that the paper-bark tree can tolerate high concentrations of iron and aluminum salts as well as high concentrations of common salt. If this proves to be the case, this tree should be a suitable substitute in our forests for the native ohia lehua, to which it is more or less closely related.

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Reports on Defoliation of Maui Koa Forests by Caterpillars

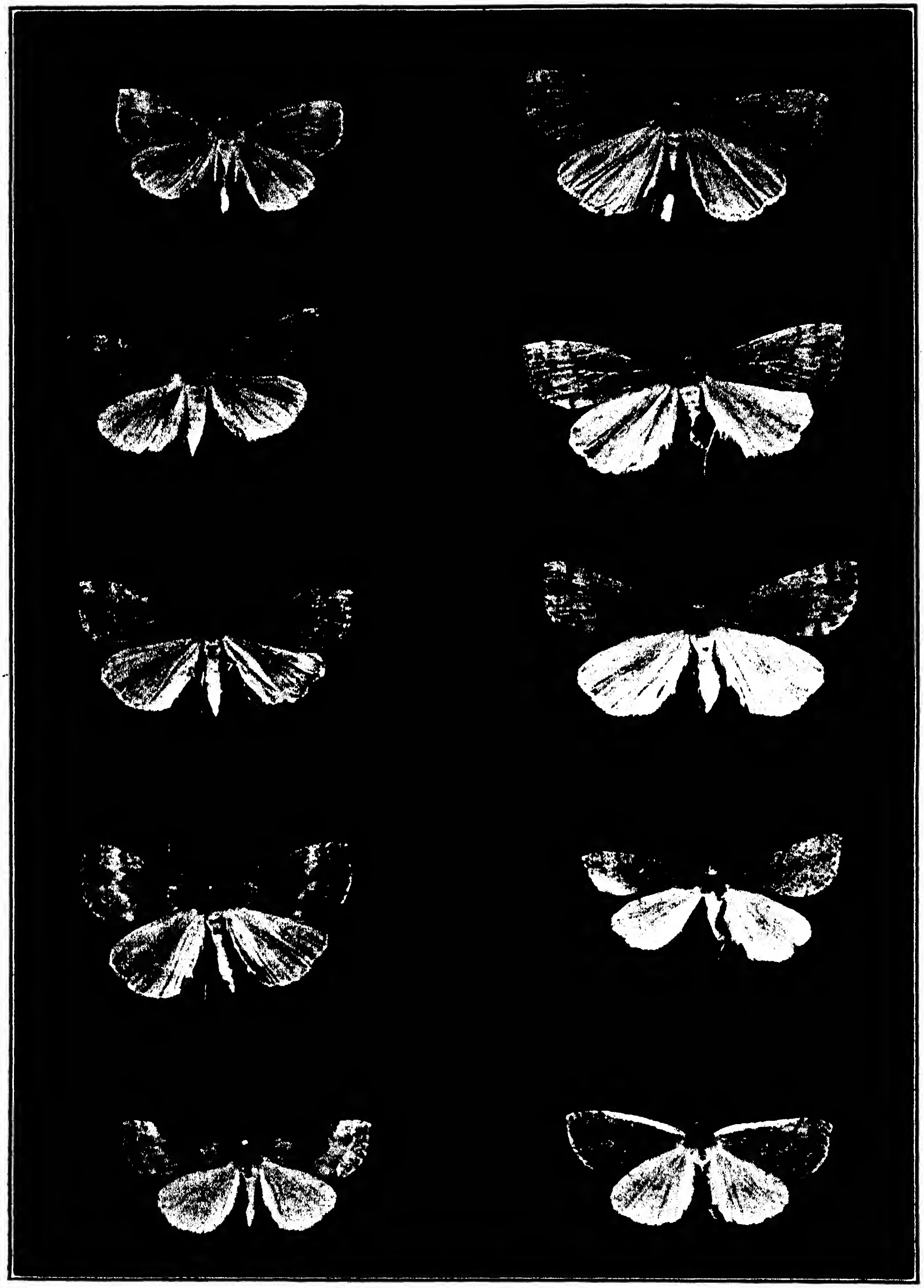
By O. H. Swezey

I hereby report on an investigation of insect injury to koa trees on Maui, January 13 to 16, 1926.

This investigation was made in company with Dr. H. L. Lyon, and Mr. F. Muir and Mr. R. H. Van Zwaluwenburg were with us on one day. It was made in response to Mr. H. A. Baldwin's reporting to Alexander & Baldwin, Ltd., that the koa forest above Haiku appeared to be seriously affected. Mr. Baldwin took us to the region on January 13.

Lying to the eastward of Olinda, at an elevation of 3,500 to 4,500 feet, is a large area composed largely of koa trees with lehua trees scattered among them and several other kinds of smaller native trees. From below, this forest area had the appearance of being dead, as the branches were devoid of foliage. On arriving at the forest and examining the koa trees, it was found that they had recently been defoliated by caterpillars. Isolated trees in gulches somewhat separated from the main forest were found to be not entirely defoliated, in some cases scarcely at all injured, and in others with a few branches which still bore foliage. From these, specimens of the caterpillars were obtained which were responsible for this extensive denudation of the trees. Their presence and the evidence of their work on these partially defoliated trees was sufficient to assign this as the cause for the extensive defoliation. They are a looping caterpillar, or measuring worm, about 1½ inches long when full-grown, varying in color from green to grey and reddish brown.

Most of the caterpillars had finished their eating and completed their growth and had disappeared. Much search was made to secure a good supply of the caterpillars to rear them and obtain the mature moth so as to determine what was the species and whether it was a new pest or a native insect. Search was also made for the pupae or chrysalids which the full-grown caterpillars form in the process of developing from caterpillar to moth. Quite a good number of the chrysalids were secured from beneath moss on logs, in and under trash on the ground, and in the soil a little below the surface. Old chrysalids from which moths had already issued were found beneath bark of tree trunks also. From the material brought to the Experiment Station, some of the moths have already matured so that we are now able to determine the species. It is *Scotorythra paludicola,* a native moth known to occur on Kauai, Maui and Hawaii. It is a brown moth with wing expanse of from 1 inch to 1½ inches. The forewing has a dark spot near the middle and two more or less wavy dark lines crossing it, and a few dark dots towards the outer extremity. The coloration varies a good deal and some specimens have a dark band across the middle of the wing occupying all the space between the wavy lines.



Koa moth, *Scotorythra paludicola.* Series of moths showing variability.

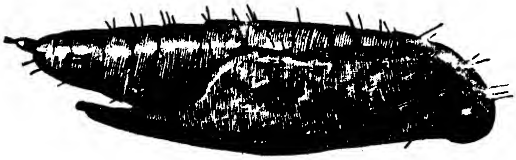
The Kula pipe line trail penetrates the denuded koa forest, and one day we followed this trail to see if the conditions were the same throughout. Along this trail, going easterly, the limits of the koa forest are reached in about three miles. The koa trees were found defoliated for the entire extent. Even the farther easterly trees were found to be defoliated like the others. These caterpillars have not attacked the other trees of the forest, except that a very few mamani trees were noted and they were defoliated by the same kind of caterpillars as were the koas.

Such an extensive defoliation of koa trees had not been observed before by any of the people of the region with whom we talked, but Mr. Pogue, of Kailua, said that he had seen a similar occurrence about thirty years ago. We made the trip one day to Keanae on the new road. Not many koa trees were to be seen near this road, but just beyond Mr. Pogue's place at Kailua a few were observed in the gulches and on ridges, and these were practically in perfect foliage. However, by diligent search I was able to secure a few of the same kind of caterpillars that had occurred in such countless thousands on the koa forest at the higher elevation*.

Dr. R. C. L. Perkins, in the *Introduction* to the *Fauna Hawaiiensis,* in discussing the habits of certain of the Lepidoptera, says, "*Acacia koa* is attacked by numerous species, and certain of these become locally and periodically so numerous, that great areas of koa forest are entirely denuded of their phyllodes. *Scotorythra idolias* on Hawaii and *S. paludicola* on Maui were responsible for two of the most severe attacks that we have witnessed. Native birds attracted in thousands by the abundance of this, one of their favorite foods, were gorged to repletion, and the starving caterpillars formed in writhing masses on the ground beneath the tall koa trees. The dropping of excrement from the trees on the dead leaves beneath made a rattling noise as of a hailstorm. In one instance it was noted that these pests of caterpillars were destroyed by an epidemic fungous disease, which attacked the full-grown larvae after their descent to the ground for pupation, as well as the pupae themselves."

Thus it is seen that the defoliation of koa forests, similar to the present one on Maui, have been known at least a few times before. No doubt it has occurred more often than attention has been called to it, or it may have occurred in less degree more frequently and not severe enough to be noticed. At any rate it is a native species of insect that is responsible in this case, a species that has developed in the Islands using the koa as a host plant, just as many other species have developed using other kinds of the forest trees as hosts. In most cases these insects do not increase to destructive numbers, being held in check by natural enemies of several kinds. This is especially the case where the forests are in their natural conditions, not having been overrun by cattle or disturbed by man in any of his projects. Note that Dr. Perkins mentions above, "the thousands of native birds feeding on the caterpillars." In the present instance, only a very few native birds were observed anywhere in the forest. It is generally known that the native birds are much scarcer nowadays than they used to be. At present

* The species of moth that later issued from this lot of caterpillars was different, however. Its identity has not yet been made out.



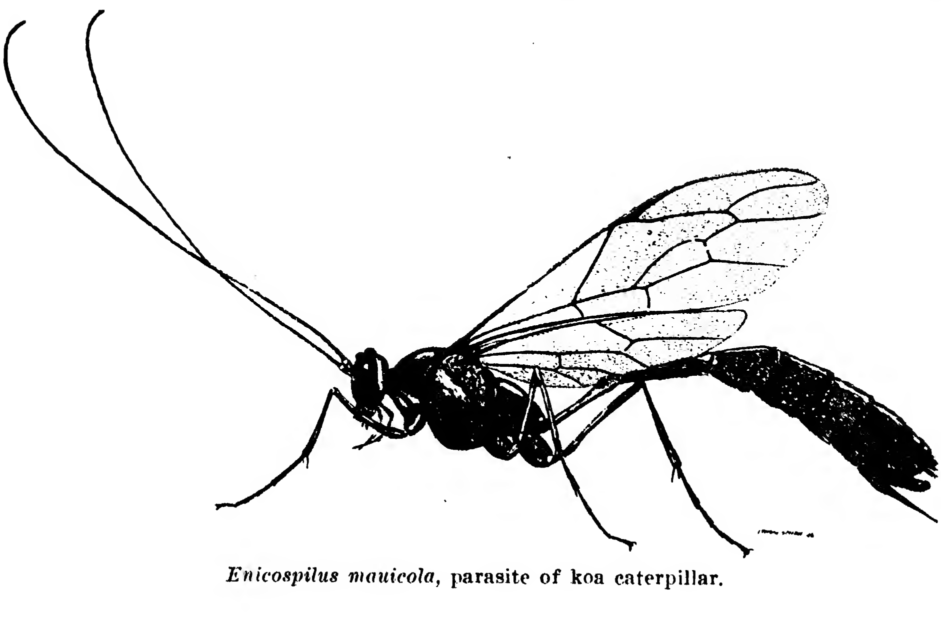
Pupa of koa moth.

they are too scarce to be much of a factor in checking an extensive caterpillar outbreak.

A large predacious bug (*Oechalia grisca*) was found quite common on the koa trees where there were any remaining caterpillars. They pierce the caterpillars with the proboscis and suck the body fluids, thus killing them, and must have been an important factor in destroying thousands of the caterpillars.

A large native parasite (*Enicospilus mauicola*) was observed abundant at one place and a few were captured. This is known to be parasitic on caterpillars. A few of the caterpillars brought to the Station had the larvae of this parasite issue from them later on. Empty cocoons of the parasite were also found in and under moss and in the soil where the caterpillars had formed their pupae.

No evidence of the fungous disease mentioned by Dr. Perkins was found. It is a common observation in studying the native insects of the forests, especially in the wet regions, to find many that have died of fungous diseases. No doubt this is one of the important factors in the control of insects in the natural forests. The region at present concerned is a normally wet region, or at least bordering on a wet region. For some months it has been unusually dry weather there, perhaps too dry for this fungous disease to be effective, and this may be one reason for the extensive increase in the numbers of the caterpillars. No doubt the present situation has resulted from a succession of broods of caterpillars covering a period of a number of months, in which each successive brood has been an increase



Enicospilus mauicola, parasite of koa caterpillar.

over the preceding one, due to conditions being such that natural enemies were not operating to keep the insect normally checked. Probably several of the preceding broods have been quite destructive, but not sufficiently so as to be noticed until the last one, which has been so numerous as to result in this complete defoliation.

The koa trees are not dead yet as a consequence, but will be much checked, and probably there will be dying back of many twigs. As there has been considerable injury to the terminal buds the trees may be very slow to put out new foliage. This should be watched to see whether it results successfully, and also as to whether it is immediately attacked and destroyed by another brood of caterpillars. A new brood should be due immediately as there must be an enormous amount of moths matured already from the brood of caterpillars that defoliated the trees, for the pupae present in the ground when we were there must have all matured by this time, as those did which we brought back with us. These moths will be depositing their eggs soon, no doubt. It is just possible that if there is no foliage on the koa trees, the moths may go elsewhere in search of koas with foliage on which to oviposit. If they should oviposit on the defoliated trees, and the young caterpillars that hatch soon should not find any food (if no new foliage has yet formed) they will starve and thus bring about a termination of the trouble. However, if foliage has already started by the time a new brood of caterpillars appears, they would quickly destroy it, and this would result more disastrously to the trees, i. e., if new foliage should be eaten off as rapidly as produced, dying of the trees might be expected.

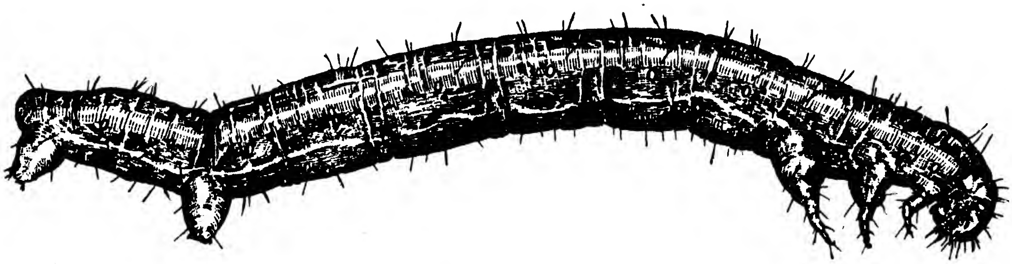
The situation should be carefully watched as to the ultimate outcome, and if possible determine the factors operating to bring about such conditions, or a continuation or repetition of such, if this is found to occur. It may require several trips at frequent intervals for a complete understanding of the situation.

If the scarcity of native insectivorous birds has been an important factor in the large increase of caterpillars, it points to the desirability of introducing forest-inhabiting, insectivorous birds to help bring back control of the caterpillars. Probably the Japanese titmouse, already well established in the mountain forests of Kauai would be quite useful. The food habits of this bird have not been studied, but they seem to be always searching for insects among the trees, and they are a lot more abundant than any of the native birds in the Kauai forests. It would be more feasible at present to introduce some of these birds to the Maui forests than to attempt introduction of other birds from foreign countries.

Another phase of the situation might be the consideration of dusting by airplane to poison the caterpillars, if there should occur a repetition of such an extensive outbreak in the region.

I hereby report on a second visit to the defoliated koa forest along the Kula pipe line eastward from Olinda, Maui, February 27, 1926.

There was no difference in appearance of the koa forest from what was present at my previous visit, six weeks before, January 13 and 14. No new growth had yet started on the defoliated trees. The tips of the twigs were dying back



Caterpillar of koa moth.

from 1 to 6 inches. It appears as though this had taken place several times before. On trees where there were still some vestiges remaining of the foliage, caterpillars were numerous in all stages, from recently hatched ones to nearly full-grown. As an indication of their abundance, twenty caterpillars were secured at one sweep of the net on a partially defoliated branch. Most of these were very small caterpillars. It indicates that the moths had matured from the previous brood of caterpillars and laid eggs which have hatched already and commenced their feeding on the remaining foliage of the koa trees. Apparently the most of them will starve to death unless they take to feeding on the foliage of other kinds of trees, for there is not enough foliage left on the koa trees to provide food for more than a few of them. Only a very few caterpillars were found on the other trees, however, and I could not distinguish whether they were of the same species or not. All that could be secured of these were brought in for rearing, in order to determine whether the same species or different species. These have not reared to maturity very successfully, but one moth reared from a *Cheirodendron* tree and another from *Coprosma* were of larger species than the koa moth. A few moths from caterpillers on ohia lehua trees are darker than the moths reared from koa (*Scotorythra paludicola*), but as the latter is a very variable species, I cannot be certain but what the moths from these two trees are the same species. However, if they are the same species, their caterpillars do not take to the lehua very well, for I secured only a few caterpillars from lehua with considerable effort. The lehua trees even in close proximity to the koa trees had no appearance of even partial defoliation by caterpillars.

On another day, a few caterpillars were collected from *Boehmeria* in Waihee Valley. The moths that matured from these very much resembled those from lehua above. They were not numerous enough to affect the trees at all on which they were feeding. The caterpillars did not resemble those obtained from koa at Olinda. No koa trees were to be seen in Waihee Valley, nor in Iao Valley, where I went also on another day.

By considerable digging in the ground, rotten logs, etc., in the Olinda forest, the empty pupa cases were found quite numerous, and only one living one was found. This indicates that the moths from the previous brood of caterpillars had practically all matured. Since they have such a preference to the koa tree, it is quite evident that most of the caterpillars that would hatch from the eggs they would lay would of necessity starve, since the koas are continuing in the defoliated condition. Perhaps this will result in checking the outbreak, so that

when the koa trees do eventually produce a new growth of foliage there will not be swarms of caterpillars to destroy it.

A few of the caterpillars brought in were found to be parasitized. Some by a Tachinid fly, *Frontina archippivora*, and some by one or more Ophionids of the genus *Enicospilus*. A few also succumbed to a fungous disease which is often very effective in killing caterpillars in the forests. Another caterpillar enemy that was abundant wherever the caterpillars were to be found was the predacious bug, *Oechalia*. There would be more of them, too, for their eggs were numerous. On the phyllodes of one small branch, I found five clusters of eggs containing 6, 6, 6, 8 and 10 eggs respectively. They were all about ready to hatch.

On March 2 to 4, I made a trip with Mr. Sam Baldwin, manager of Haleakala Ranch, to Waiopai, a tract of land on the south slope of Haleakala which the ranch utilizes. What forest there is, is chiefly above 4,000 feet elevation. The cattle roam as high as 4,000 feet, and what koa trees are left are in the gulches, hence do not form a continuous forest. These koa trees were not defoliated, though I found a few caterpillars on the foliage. They were mostly similar to those at Olinda, with a good proportion of green ones, but the larger number were of a reddish or brownish coloration, quite variable. The moths that reared from these were all the same as at Olinda, even from the green ones as well. Parasites and predators were present here also, as on the Olinda side of the mountain.

The foliage on some of these koas had a reddish tinge. This was found to be due to the presence of "red spider," a species of mite. Apparently these had been more abundant than at the time I was there, but it did not seem that the trees were very seriously affected by them. These mites were observed to some extent in the Olinda forest also. A few of the little black ladybeetle, *Stethorus vagans*, were found feeding on the mites.

Since making these observations on the koa trees on Maui, I have been giving attention to the koas on Oahu whenever there was opportunity. I have not seen any defoliation anywhere, but have secured two and three kinds of caterpillars*. They are always scarce. In all my experience in the forests of Oahu, I have never seen the koas defoliated by caterpillars. Once in 1911, I came upon a tree at the head of Pauoa Valley that had a good many caterpillars on it, and approached the nearest to defoliation of any that I have seen on this Island.

I wrote to Dr. Perkins about my January visit to the Olinda defoliated koa forest, and it will be of interest to quote from his letter of February 15, what he says about his observations on similar occurrences:

In the early days of my collecting, I saw the koa trees stripped almost every year in one locality or another. In 1892, the trees of the wet belt in Kona—presumably by *Scotorythra idolias*, but I did not breed any; in 1893, I was not in any koa district, but in 1894 and 1895 the Haleakala forest of koa, 4,000 to 5,000 feet, was stripped for miles by *S. paludicola*, and in the latter year also all the dry koa forest near Kilauea (as also again in some later years) by *S. idolias*, though there may have been some *paludicola* also. In 1895 or 1896, all the koas at 3,500 feet were again stripped in Kona. In 1900, the koa trees on Tantalus were many of them quite stripped, but more than one species of caterpillar was

* From these, *Scotorythra rara* and *Scotorythra caryopis* issued in due time.

present, *metacrossa* being certainly the smaller and probably *rara* the larger species. I do not remember to have seen any total stripping of trees after 1900, but then I had not much opportunity later. Stripped koas generally at first put out leaves all over instead of phyllodes, and in bad cases get so weakened that *Plagithmysus* and *Neoclytarlus* beetles attack them.

I think I have recorded somewhere how the native birds in Kona—when birds were extremely abundant there—would gorge on these caterpillars till one might see individual birds so lethargic as to be scarcely willing to fly. When the mynah birds reached the height of their abundance in the forests, I believe the defoliation by these caterpillars really became much less frequent, but in 1892 it was a familiar sight to the old natives, who spoke of it as occurring frequently, though not necessarily every year.

From Dr. Perkins' experience, we can expect that the koa trees will recover in the Olinda forest. I expect, however, that many of them are likely to be so much weakened as to become a prey to other insects, and that it may result in the death of some of them, especially as the long drought has been somewhat detrimental to them anyway. I shall expect to make another trip to this forest in May or June to keep track of developments there.

I hereby report on a third visit to the defoliated koa forest at Olinda, Maui, May 13, 1926.

There is scarcely any difference in appearance from that of my previous visit, February 27. On those koa trees which had had some remaining foliage a little growth has taken place, and a few even are in bloom. But where the defoliation by caterpillars had been complete no new growth has started yet, except that occasionally in a tree are small bunches of numerous new twigs, scattered in the tree top. It is more apparent that there will be much dying back of twigs, and even larger branches, and possibly whole trees, but as to the final outcome time alone will tell. Already native beetles that attack dead or dying koa twigs, branches, or trees, are present. I found *Proterhinus* beetles on the dead twigs, and in small dead branches were the larvae of Cerambycid beetles, several species of which live in dead koa wood.

Caterpillars are scarce on koa now. Only a very few tiny caterpillars were found on any accessible foliage, where they had been numerous before. Search was made for caterpillars on the other kinds of trees and shrubs. Only an occasional one was found on anything except the native raspberry (*Rubus macraei*), a good deal of which is present in the region. The Rubus bushes had made considerable recent new growth, and the eating of the caterpillars was not conspicuous. However, by beating about with the insect net I was able to get a few caterpillars from the Rubus leaves most anywhere. These caterpillars looked the same as those that had previously been so numerous on the koa trees. I brought back quite a number for rearing the moths to determine if they were of the same species or not. None has been reared yet. The only one that has pupated had a maggot of the Tachinid fly, *Chaetogaedia monticola* in it. The pupa, however, resembled that of *Scotorythra paludicola* which I had previously reared from koa. *Mermis* worms issued from several of the caterpillars, resulting in their death. My remaining caterpillars give little promise of producing moths. Apparently the

change of climate, coming down to the dry hot climate prevailing in Honolulu of late has not agreed with them. Their food plant became exhausted also, and though they eat koa, which I have given them, they do not seem to thrive on it. It is of interest to determine the habits of the various caterpillars found in the Olinda forest, with special reference to the recent outbreak on koa, but to do this properly will require spending considerable time there at some convenient future time.

Losses Caused by Mosaic in H 109 Plant Cane

We have recently completed a test having to do with the effect of mosaic on the yields of H 109 plant cane. The test was in a field of an Oahu plantation. The work was carried on by Mr. Denison, of Waipio.

The field in question showed early signs of infection to the extent of perhaps 20 per cent in some areas.

In December, 1924, 50 average stalks were selected as nearly as possible of the same size. Half of these were healthy and half were diseased. None of the 25 original healthy stalks contracted mosaic during the period of the experiment, although they were in the immediate vicinity of the diseased stalks. Growth measurements were made every two weeks.

The experiment was harvested on April 28, 1926.

During this period the healthy stalks made 2.06 feet more growth than the diseased ones and each weighed three-fourths of a pound more.

Each stalk was run through the hand mill separately and the juice analyzed. Borer damaged stalks were discarded.

The following were the juices obtained:

	Weight per stalk	Brix	Pol.	Purity	Q. R.
Healthy	9¼ pounds	18.99	17.52	92.1	7.41
Mosaic	8½ pounds	17.42	15.35	88.5	8.57

We have, in this instance, a very distinct deterioration in the quality of cane caused by mosaic. This amounted to a decrease of 3.6 in purity and an increase of 1.16 in the quality ratio.

Assuming healthy cane as 100 per cent, we have constructed the following table showing losses to be expected if a field of H 109 were 100 per cent mosaic infected from the time of start:

	T. C. P. A.	Q. R.	T. S. P A.
Healthy	100	7.41	13.49
Mosaic	92	8.57	10.73
Loss in Yield	8	1.16	2.76
Loss in Per Cent	8	15.6	20.5

J. A. V. and F. C. D.

The Identification of Sugar Cane Varieties

Owing to the large number of seedlings being propagated and tested on the plantations, a method of identification is needed in order to avoid confusion and possible errors that may prove costly. A practical means of identifying cane varieties by photographs is now being studied. In addition to picturing sections of the stalk, enlarged photographs of representative eyes or buds are made. The characteristic formation and hairing of the bud as pointed out by Jeswiet is thus taken advantage of without resorting to the slower and more expensive method of making pen and ink drawings. We show here, as examples of the work we are doing, the pictures of four varieties, the quarter-bred Uba seedlings bearing the numbers 25 Q 13, 25 Q 16, 25 Q 18, 25 Q 19. These are seedlings of U. D. 1 pollinated by D 1135. U. D. 1, in turn, is a seedling of Uba pollinated by D 1135. The seedlings therefore are one-quarter Uba and three-quarters D 1135.

While the stalks in the photographs show differences in each case, these differences are not such as to permit of ready identification and lack the striking contrasts so clearly brought forth in the enlarged bud photographs. These are such as to aid materially in distinguishing between different cane varieties even though the parentage, as in these instances, may be identical.

The pictures in each case are supplemented by descriptions which are filed with the photographs. For example, we give the description of one of them as follows:

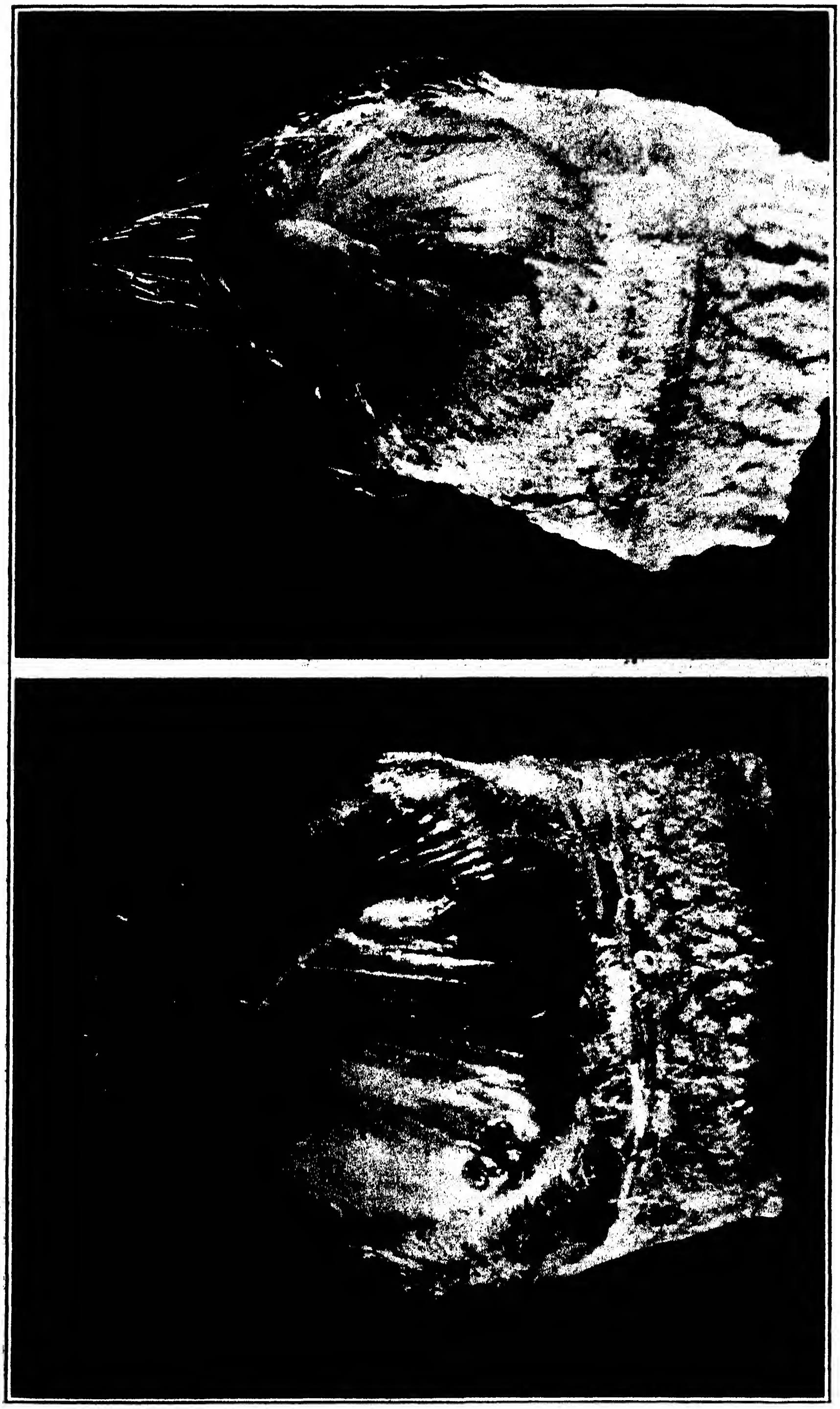
Date: May 6, 1926.
Variety: 25 Q 19.
Place: Makiki Field 9B.
Age: 14 months—original stool.
General Appearance: Erect type.
Color: Young stalks, green; later, tan with red; little wax.
Eye: Prominent and humped.
Parents: U. D. 1 x D 1135.
Stalk: Fairly good; dirty.
Leaf: Erect, little overhanging, hairy sheath.
Top: Very weak; D 1135 type.
Stooling: Good, plenty of suckers.
Ratooning: ——————
Rind: Hard.
Disease or Pests: Borer.
Juice: 9.5 Q. R., ten months old.
Rating: Fair.
Remarks: ——————

The variety 25 Q 13 frequently has bud abnormalities, as shown in Fig. 1.

In future articles we shall report the progress of this study, using some of the seedlings that are showing up prominently in the plantation tests. In this instance, the canes pictured to introduce the subject were chosen for other reasons than their commercial significance.

T. S.

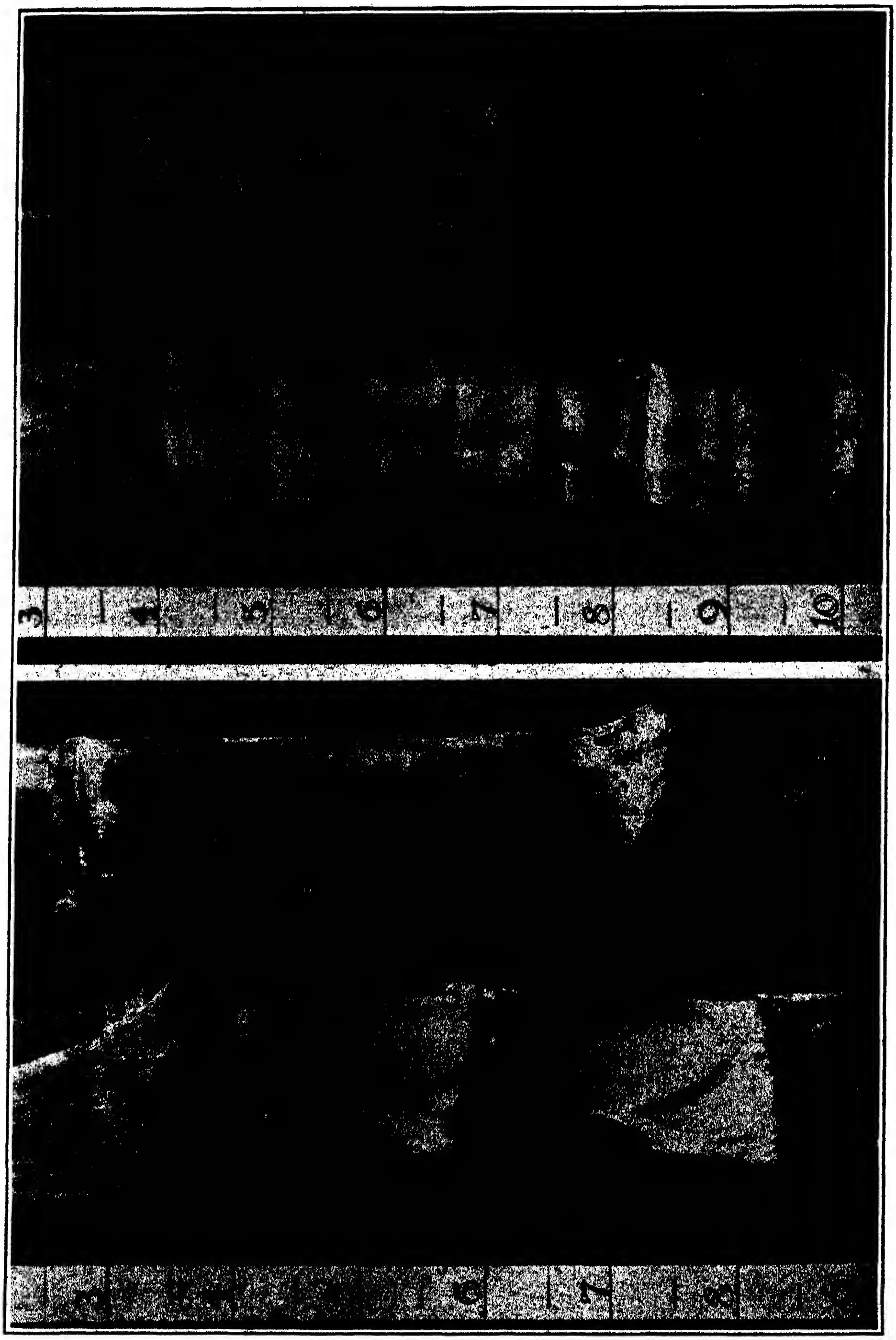
Fig. 1. 25 Q 13.



25 Q 13

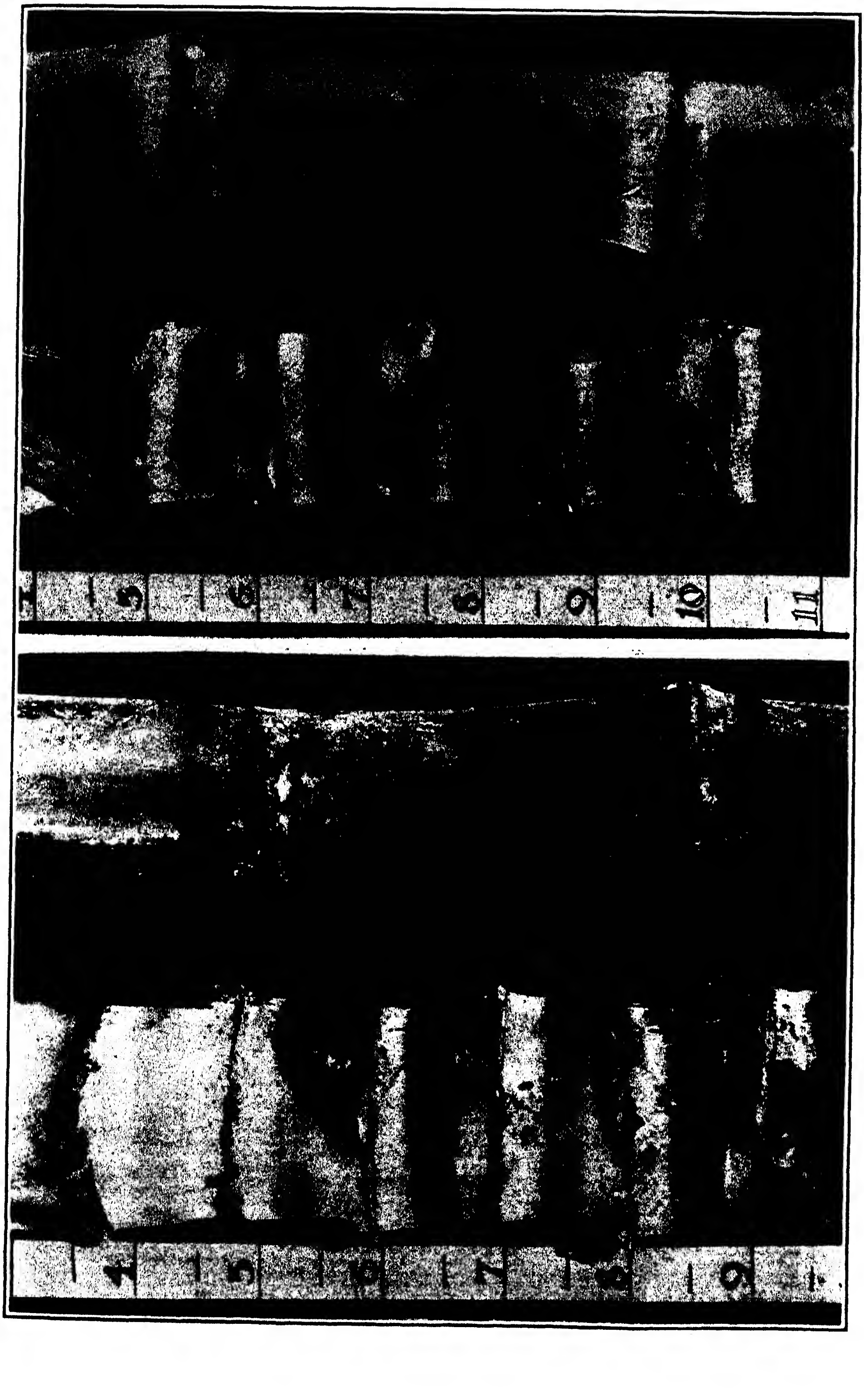
25 Q 18

Fig. 2



25 Q 18 25 Q 13

Fig. 3



25 Q 16

25 Q 19

Fig. 4

25 Q 16 Fig. 5 25 Q 19

Uba Hybrids

By J. A. Verret

We give herewith data from a recent harvest of a number of Uba hybrids growing at Makiki. These data are not conclusive as they are based on 10-foot sections, with no repetitions, but they do give interesting indications of the value of some of these canes.

We give herewith a list of the more promising ones:

CANE FROM MAKIKI PLOTS—18 MONTHS OLD AT HARVEST EARLY IN FEBRUARY

	Tons per Acre		
Variety	Cane	Q. R.	Sugar
U. D. 100	108.0	10.44	10.35
U. D. 88	84.6	8.53	10.00
U. D. 75	113.3	11.40	9.94
U. D. 79	87.8	8.90	9.87
U. D. 106	97.9	10.23	9.57
U. H. 3	78.1	8.27	9.44
U. H. 2	70.7	7.76	9.12
U. D. 42	86.8	9.57	9.07
H 109	70.2	7.91	8.80
U. D. 23	79.1	9.02	8.77
U. D. 66	70.4	8.22	8.56
U. D. 39	64.5	7.56	8.53
U. D. 92	68.8	8.14	8.45
U. D. 1	60.8	7.22	8.42
H 109	60.3	7.23	8.33
U. D. 104	72.5	8.98	8.07
U. H. 1*	54.2	6.88	7.85

Several others of these canes are of promise, but as seed was taken we do not have comparative yields. Among these are U. H. 1, U. D. 58 and U. D. 62.

These canes have been sampled a number of times. As a whole they have poor juices. This applies especially to the Uba x D 1135 crosses. The Uba x H 109 has much better juice (see U. H. Nos. 1 to 4), and we feel that it is a more promising cross than Uba x D 1135, but it is much more difficult to obtain good H 109 pollen at the proper time. An exception to the above is U. D. 1, a cross between Uba x D 1135. We have found this cane to have consistently good juices.

Among the consistently poor juice canes are listed the following: U. D. 10, 11, 12, 14, 19, 21, 28, 31, 33, 34, 38, 41, 53, 57, 67, 69, 94, 95, 96, 101, 102 and 107. The very worst of these are: U. D. 14, 19, 31, 53, 57 and 101. We feel that the record of these particular canes shows them to have such poor juices as to be of no commercial value, and that they should not be spread on the plantations unless further careful tests show them to have worth while juices.

* Some seed taken from young cane.

QUALITY RATIOS OF UBA HYBRID CANES

Variety	Makiki Cane 18 Mos.	Makiki Cane not ripened	Makiki Cane 12 Mos.	Manoa Cane 14 Mos. Sampled in February
U. H. 1	6.88	9.33	8.3	9.4
U. H. 2	7.76	30.43	11.5	23.5
U. H. 3	8.27	17.60	10.6	51.8
U. H. 4	8.74	15.12	...	30.5
U. B. 1	12.47	15.60	10.5	23.8
U. B. 3	8.42	11.01	8.3	21.1
Honokaa U. H. 1	9.13	....	...	....
Honokaa U. H. 2	14.43	....	...	....
U. D. 1	7.31	9.56	7.8	11.2
U. D. 6	7.55	12.04	9.5	12.4
U. D. 7	7.86	12.25	12.2	21.3
U. D. 9	11.20	14.22	11.4	12.8
U. D. 10	17.39	21.27	9.6	83.9
U. D. 11	12.31	20.17	14.0	49.7
U. D. 12	17.25	16.39	12.4	13.7
U. D. 13	10.22	10.95	13.6	10.5
U. D. 14	25.25	46.77	22.2	48.7
U. D. 18	10.13	20.97	11.3	27.2
U. D. 19	18.58	16.19	9.5	18.5
U. D. 20	10.17	17.41	12.4	11.6
U. D. 21	26.28	21.92	10.6	36.3
U. D. 22	....	73.11	...	15.2
U. D. 23	9.02	22.32	16.7	13.5
U. D. 25	8.77	16.23	12.9	11.8
U. D. 26	10.21	15.93	11.2	13.7
U. D. 28	12.49	24.00	...	22.8
U. D. 30	10.58	15.14	29.8	24.9
U. D. 31	27.38	28.05	23.6	27.5
U. D. 32	10.13	13.31	...	14.2
U. D. 33	14.74	14.47	15.6	18.7
U. D. 34	14.27	13.21	19.7	16.7
U. D. 35	12.42	13.00	10.3	43.4
U. D. 36	13.17	16.49	9.6	19.6
U. D. 37	15.73	12.41	14.7	12.4
U. D. 38	28.97	20.80	17.4	75.8
U. D. 39	7.56	9.27	16.7	12.9
U. D. 40	14.51	23.45	11.5	18.0
U. D. 41	13.86	16.63	17.3	30.2
U. D. 42	9.58	10.54	13.1	11.3
U. D. 47	8.64	19.60	...	28.9
U. D. 49	9.21	52.92	...	115.8
U. D. 50	9.34	12.73	...	12.2
U. D. 51	9.93	19.15	...	15.3
U. D. 52	12.12	19.31	20.3	14.0
U. D. 53	16.39	32.72	15.4	39.8
U. D. 55	12.82	46.58	...	40.6
U. D. 56	10.95	13.00	14.9	13.6
U. D. 57	16.03	50.20	51.3	45.9
U. D. 58	14.71	17.30	12.0	15.5
U. D. 60	9.50	18.83	14.5	18.9

U. D. 61	11.06	15.73	18.8	14.2
U. D. 62	10.16	21.41	...	27.2
U. D. 64	10.12	28.28	18.8	40.6
U. D. 65	9.88	15.26	...	19.3
U. D. 66	8.22	15.24	10.5	13.5
U. D. 67	13.11	14.44	...	15.6
U. D. 68	9.00	20.97	16.1	20.7
U. D. 69	11.88	154.48	28.7	18.5
U. D. 70	9.79	16.98	13.8	17.1
U. D. 71	11.33	16.82	14.9	30.6
U. D. 73	12.02	12.35	12.4	11.0
U. D. 75	11.40	20.79	13.3	14.7
U. D. 76	10.88	8.97	10.1	9.3
U. D. 78	9.74	18.71	...	16.7
U. D. 79	8.90	17.37	16.4	11.1
U. D. 80	9.80	18.93	...	11.0
U. D. 81	10.56	10.91	11.9	15.9
U. D. 82	31.69	10.24	9.6	11.1
U. D. 83	9.12	10.55	9.0	13.3
U. D. 85	14.02	15.78	11.6	16.4
U. D. 86	9.53	14.35	11.1	13.8
U. D. 88	8.53	14.92	10.8	18.7
U. D. 90	10.73	111.53	14.3	32.4
U. D. 91	10.57	13.39	14.2	18.3
U. D. 92	8.14	36.78	13.5	14.5
U. D. 94	25.24	10.75	32.0	17.7
U. D. 95	20.11	28.62	...	11.1
U. D. 96	13.10	16.24	...	18.4
U. D. 97	13.35	11.85	10.7	17.1
U. D. 100	10.44	14.03	11.8	16.2
U. D. 101	18.53	16.96	18.9	29.5
U. D. 102	21.57	23.89	37.2	28.4
U. D. 103	8.45	14.13	...	15.3
U. D. 104	8.98	13.35	10.8	14.2
U. D. 105	9.88	49.17	14.8	35.3
U. D. 106	10.23	13.41	15.7	12.6
U. D. 107	28.42	23.00	...	42.6
U. D. 108	10.44	15.21	11.2	15.8
U. D. 110	9.18	11.21	13.2	18.2
H 109	7.57	....	...	....
Uba	....	....	...	25.2
Striped Tip	....	....	...	12.3
Striped Tip	....	....	...	12.4
Striped Tip	....	....	...	9.8

MAKIKI PLOTS, FIELD 5, UBA AND HONOMU SEEDLINGS, AGE 18 MONTHS, HARVESTED IN FEBRUARY, 1926

Location	Seedling No.	Total Stalks	Injured	Total Weight, Lbs.	Length of Line	Lbs. per Foot	T. C. P. A. (Gross Area)	Q. R.	T. S. P. A. (Gross Area)	Remarks (Notes taken in the field)
							(With correction for outside lines)			
	U. H. 1	170	14	387	25′	15.5	54.02	6.88	7.85	Slight damage by rats and borers. Seed taken in 1925.
	U. H. 2	212	6	507	25′	20.3	70.74	7.76	9.12	Not very uniform.
Outside line	U. H. 3	289	0	699	25′	28.0	78.10	8.27	9.44	Clean cane.
Outside line	U. H. 4	141	0	413	25′	16.5	....	8.74	...	Uniform clean cane. Seed taken in 1925.
	U. B. 1	187	6	496	25′	19.8	69.00	12.47	5.53	Damaged by rats.
	U. B. 3	142	142	230	25′	9.2	32.06	8.42	3.81	All damaged by rats.
	Honomu 1	220	10	767	50′	15.3	53.32	9.73	5.59	Fairly uniform cane. Slight rat damage.
	Honomu 2	391	42	964	50′	19.3	67.26	9.25	7.27	Fairly uniform cane. Slight rat damage.
	Honomu 8	212	16	841	50′	16.8	58.54	8.10	7.23	Good uniform and clean cane.
Outside	Honokaa U. H. 1	...	..	731	35′	20.9	51.0	9.13	5.59	Very large number of very small stalks. Not a commercial cane.
Outside	Honokaa U. H. 2	156	2	385	32′	12.0	41.82	14.43	2.90	Fairly uniform. Slight rat damage.
Outside	H 109	89	11	453	18′	25.2	70.20	7.91	8.80	Some rat damage.
Outside	H 109	44	0	371	15′	24.7	60.30	7.23	8.33	Clean cane.
Outside	U. D. 6	168	7	446	20′	22.3	54.4	7.55	7.20	Fairly uniform and clean cane.
Outside	U. D. 7	207	5	490	20′	24.5	59.8	7.86	7.60	Fair cane. Slight borer damage.
	U. D. 9	154	0	371	20′	18.6	64.82	11.20	5.79	Fair.
	U. D. 10	158	42	411	20′	20.6	71.78	17.39	4.13	Uneven, staggered, broken. Not a commercial cane.
	U. D. 11	136	2	241	20′	12.1	42.17	12.31	3.43	Poor, very uneven and staggered. Slight rat damage. Not a commercial cane.
	U. D. 12	193	3	236	20′	11.8	41.12	17.25	2.38	Very small stalks, staggered. Not a commercial cane.
	U. D. 13	169	3	427	20′	21.4	74.58	10.22	7.30*	Node gall. Uneven. Not a commercial cane.

	U. D. 14	290	29	496	20′	24.8	86.42	25.25	3.42*	Very staggered and uneven. Slight node gall. Rats and borers. Not a commercial cane.
	U. D. 18	138	17	286	20′	14.3	49.82	10.13	4.92*	Staggered, uneven. Rats, borer. Slight node gall.
	U. D. 19	254	33	313	20′	15.7	54.71	18.58	2.94	Very poor type of cane. Staggered, uneven. Not a commercial cane.
	U. D. 20	186	3	425	20′	21.3	74.22	10.17	7.30*	Uniform, clean cane. Very slight node gall.
	U. D. 21	168	8	485	20′	24.3	84.34	26.28	3.21	Fair cane.
	U. D. 22	0	0	0		0	0	0	0	No cane on the ground. Shaded out. Seed taken in 1925?
	U. D. 23	203	2	453	20′	22.7	79.10	9.02	8.77	Fairly even and clean cane.
Outside	U. D. 25	145	1	553	20′	27.7	77.2	8.77	8.81*	Node gall—otherwise good cane.
Outside	U. D. 26	173	1	398	20′	19.9	55.4	10.21	5.43	Fairly even and clean.
Outside	U. D. 28	123	0	422	20′	21.1	51.5	12.49	4.12*	Node gall. Fair cane.
Outside	U. D. 30	175	8	714	20′	35.7	87.1	10.58	8.23*	Fairly clean and uniform. Node gall.
	U. D. 31	149	5	278	20′	13.9	48.44	27.38	1.77	Small stalks and staggered. Not a commercial cane.
	U. D. 32	79	5	259	20′	13.0	45.30	10.13	4.47*	Poor. Node gall. Not a commercial cane.
	U. D. 33	138	0	443	20′	22.2	77.36	14.74	5.25	Fair. Slightly uneven and staggered.
	U. D. 34	137	15	367	20′	18.4	64.12	14.27	4.49	Fair. Uneven and staggered.
	U. D. 35	151	6	552	20′	27.6	96.18	12.42	7.74*	Slight node gall. Uneven, slight borer.
	U. D. 36	141	2	472	20′	23.6	82.24	13.17	6.24	Fair. Slight rat damage.
	U. D. 37	173	13	368	20′	18.4	64.12	15.73	4.08	Fairly clean cane. Some broken.
	U. D. 38	52	10	155	20′	7.8	27.18	28.97	0.94	Poor. Slight rat damage. Not a commercial cane.
	U. D. 39	157	1	369	20′	18.5	64.47	7.56	8.53	Fairly uniform and clean cane.
	U. D. 40	139	4	482	20′	24.1	83.98	14.51	5.79	Fairly clean cane.
	U. D. 41	107	12	309	20′	15.5	54.02	13.86	3.90	Fair.
	U. D. 42	168	1	497	20′	24.9	86.77	9.57	9.07	Fairly uniform and clean cane.
Outside	U. D. 47	0	0	0		0	0	8.64	0*	Very bad node gall.
Outside	U. D. 49	160	1	211	20′	10.6	29.50	9.21	3.21	Poor. Not uniform. Not a commercial cane.
Outside	U. D. 50	31	0	179	20′	9.0	....	9.34	...	Large stalks. Good cane. Seed taken in 1925.
Outside	U. D. 51	112	8	366	20′	18.3	63.77	9.93	6.42	Uniform and clean.

* Node gall.

Location	Seedling No.	Total Stalks	Injured	Total Weight, Lbs.	Length of Line	Lbs. per Foot	T. C. P. A. (Gross Area)	Q. R.	T. S. P. A. (Gross Area)	Remarks (Notes taken in the field)
							(With correction for outside lines)			
	U. D. 52	138	10	497	20′	24.9	86.77	12.12	7.16	Small stalks. Staggered.
	U. D. 53	129	19	338	20′	16.9	58.90	16.39	3.59	Small stalks. Staggered and broken. Not a commercial cane.
	U. D. 55	146	6	358	20′	17.9	62.38	12.82	4.86	Fair.
	U. D. 56	116	17	341	20′	17.1	59.59	10.95	5.44	Fair.
	U. D. 57	166	8	629	20′	31.5	109.77	16.03	6.85	Fairly even and clean cane.
	U. D. 58	60	0	244	20′	12.2	....	14.71	...	Uniform cane and fairly clean. Seed taken in 1925.
	U. D. 60	130	0	312	20′	15.6	54.36	9.50	5.72	Fair.
	U. D. 61	96	7	279	20′	14.0	48.78	11.06	4.41	Fair.
	U. D. 62	101	1	440	20′	22.0	....	10.16	...	Good uniform, clean cane. Seed taken in 1925.
	U. D. 64	118	2	408	20′	20.4	71.09	10.12	7.02	Fair.
	U. D. 65	29	0	116	20′	5.8	....	9.88	...	Uniform and clean cane. Shaded in. Seed taken in 1925.
	U. D. 66	120	0	403	20′	20.2	70.39	8.22	8.56	Small stalks. Clean cane.
Outside line	U. D. 67	27	...	36	20′	1.8	6.27	13.11	0.48*	Very bad node gall.
Outside line	U. D. 68	186	16	411	20′	20.6	57.4	9.00	6.38	Small stalks. Large number of lalas. Not a commercial cane.
Outside line	U. D. 69	175	20	312	20′	15.6	38.1	11.88	3.21	Small stalks. Fair.
Outside line	U. D. 70	90	5	554	20′	27.7	67.6	9.79	6.90	Fairly uniform and clean. Slight borer.
	U. D. 71	173	6	421	20′	21.1	73.53	11.33	6.49	Uneven and staggered.
	U. D. 73	229	0	341	20′	17.1	59.59	12.02	4.96	Small and staggered. Fair.
	U. D. 75	216	6	649	20′	32.5	113.26	11.40	9.94	Fairly uniform and clean cane.
	U. D. 76	315	8	334	20′	16.7	58.20	10.88	5.35	Small and uneven. Rats and borers. Not a commercial cane.
	U. D. 78	44	0	148	20′	7.4	....	9.74	...	Fairly uniform. Seed taken in 1925.
	U. D. 79	167	8	503	20′	25.2	87.82	8.90	9.87	Fairly uniform and clean.

	U. D. 80	148	6	395	20′	19.8	69.00	9.80	7.04	Fair. Small stalks and staggered.
	U. D. 81	178	4	430	20′	21.5	74.92	10.56	7.09	Small and uneven. Not a commercial cane.
	U. D. 82	131	18	252	20′	12.6	43.91	31.69	1.39	Poor. Small stalks. Rat eaten. Not a commercial cane.
	U. D. 83	39	1	150	20′	7.5	26.14	9.12	2.87	Fair. Straight cane.
	U. D. 85	96	0	250	20′	12.5	43.56	14.02	3.11	Small uneven stalks. Staggered. Not a commercial cane.
	U. D. 86	151	0	339	20′	17.0	59.24	9.53	6.22	Uneven. Fair.
Outside line	U. D. 88	211	2	611	20′	30.6	84.6	8.53	10.00	Slight node gall. Large number of fairly clean, uniform stalks.
Outside line	U. D. 90	190	4	357	20′	17.9	49.9	10.73	4.65	Small and uneven. Staggered. Not a commercial cane.
Outside line	U. D. 91	201	6	415	20′	20.8	50.80	10.57	4.80	Small and staggered.
Outside line	U. D. 92	156	4	564	20′	28.2	68.80	8.14	8.45	Uniform. Fairly clean.
	U. D. 94	168	38	395	20′	19.8	69.00	25.24	2.73	Small and staggered.
	U. D. 95	57	25	76	20′	3.8	13.24	20.11	0.66	Small. Much dead cane. Shaded in. Not a commercial cane.
	U. D. 96	106	10	380	20′	19.0	66.21	13.10	5.05	Fair.
	U. D. 97	178	5	430	20′	21.5	74.92	13.35	5.61	Fair.
	U. D. 100	144	2	619	20′	31.0	108.03	10.44	10.35	Very good uniform and clean cane.
	U. D. 101	196	12	364	20′	18.2	63.42	18.53	3.42	Small and uneven.
	U. D. 102	126	2	284	20′	14.2	49.49	21.57	2.29	Uneven and staggered. Not a commercial cane.
	U. D. 103	63	3	322	20′	16.1	56.10	8.45	6.64	Fair.
	U. D. 104	131	15	415	20′	20.8	72.48	8.98	8.07	Fairly clean cane.
	U. D. 105	126	5	431	20′	21.6	75.27	9.88	7.62	Fair.
	U. D. 106	132	10	561	20′	28.1	97.92	10.23	9.57	Fairly uniform and clean.
	U. D. 107	106	50	53	20′	2.7	9.41	28.42	0.33	Very small stalks. Not a commercial cane.
Outside line	U. D. 108	82	2	161	20′	8.1	....	10.44	...	Poor. Very small spindly stalks. Not a commercial cane.
Outside line	U. D. 110	98	2	514	20′	25.7	71.70	9.18	7.81	Fairly uniform.
Field 10	U. D. 1	171	3	545	25′	21.8	60.80	7.22	8.42	Clean cane.
Field 10	U. D. 1	...	..	...	..	...	....	7.39	...	Sample only.

* Node gall.

The "net yields" were deducted by 20% in order to make the figures more nearly comparable to plantation conditions. Also the outside lines were further deducted by 20% for mauka outside lines and 30% for makai ones. This makes a more even comparison among the seedlings.

An Explanation of the Decrease in Purity Between Clarified Juice and Syrup

By H. F. Bomonti

At the request of one of the factories, the writer investigated the decrease in purity between the clarified juice and syrup which was indicated by the laboratory figures.

The clarified juice purity at this factory represents the purity of all the juice entering the evaporator. Under these conditions there is only one thing which will cause a decrease in purity, that is, the inversion of sucrose.

If, however, there is a constant error in the analysis of the syrup sample, a decrease in purity can be secured.

In order to find out whether there was any inversion of sucrose, samples of both clarified juice and the diluted syrup were composited for a twenty-four hour period and analyzed for glucose and polarization. These composite samples were preserved with bichloride of mercury. By comparing the ratios of glucose to polarization of the clarified juice and syrup, any inversion of sucrose during this phase of the process would become apparent. A small increase in glucose will show a pronounced change in the ratio of glucose to polarization.

Glucose was determined by a volumetric method which is unusually simple and accurate. It is known as the Methylene Blue method and is fully outlined in *Facts About Sugar*, November, 1923. Several known mixtures of glucose and sucrose were tested by the method, giving extremely accurate results.

The following tabulation (Table I) gives the analyses of the composite samples for a two-week period, starting January 8:

TABLE I

	Clarified Juice					Syrup (diluted 1-5)					
Date	pH	Pol.	Pur.	Gluc.	Gluc. Pol.	pH	Pol.	Pur.	Gluc.	Gluc. Pol.	Difference between clarified juice and syrup
1926											
Jan. 8	7.3	10.98	85.79	.50	4.554	7.2	11.14	84.77	.53	4.758	—1.02
" 9	7.3	11.37	85.56	.52	4.573	7.4	11.29	85.27	.53	4.694	—0.29
" 11	7.4	11.56	86.08	.52	4.499	7.3	11.23	85.86	.51	4.542	—0.22
" 12	7.3	11.34	85.07	.54	4.762	7.25	11.29	85.19	.56	4.960	+0.12
" 13	7.3	11.34	84.95	.57	5.026	7.25	11.47	85.10	.58	5.057	+0.15
" 14	7.5	11.78	86.18	.54	4.584	7.4	11.16	85.54	.52	4.414	—0.64
" 15	7.5	12.01	87.28	.50	4.164	7.5	11.02	86.59	.45	4.084	—0.69
" 16	7.45	11.76	86.47	.51	4.337	7.36	11.16	86.09	.50	4.480	—0.38
" 18	7.57	12.12	87.57	.50	4.126	7.5	11.63	87.51	.49	4.213	—0.06
" 19	7.57	11.92	87.58	.49	4.111	7.5	11.67	86.95	.49	4.200	—0.63
" 20	7.6	11.85	87.71	.49	4.135	7.6	11.80	87.61	.49	4.153	—0.10
" 21	7.6	11.46	86.82	.54	4.712	7.6	11.66	86.99	.55	4.717	+0.17
Average	7.4	11.62	86.42	.52	4.475	7.4	11.38	86.12	.52	4.57	—0.30

Inspection of the above tabulation shows that the average increase in the ratio of glucose to polarization in the diluted syrup sample is small, amounting to about .01 per cent glucose. In no case does the increase in glucose account for the decrease in purity where the decrease is large. The average figure for two weeks shows a decrease in purity of 0.30, while the increase in glucose only accounts for about one-fourth of this amount.

The pH values of the clarified juice and syrup samples were fairly uniform, as indicated by the figures given in the tabulation. Hourly samples for pH show some variation, but they are not low enough to be a serious factor even under the existing operating conditions.

The analyses of the syrup samples in Table I were made by diluting the syrup (1:4 dilution) with tap water. An analysis of this tap water showed that there was .05 per cent inorganic matter in the water, which affected the Brix about 0.10 per cent.

The salt content of the tap water might easily vary from time to time, which explains the variations of the decrease in purity which occurred at this factory.

By substituting distilled water for tap water when diluting syrup samples, a slight increase in purity of the syrup was secured. In Table II are tabulated the purities of clarified juice and syrup for seven weeks during which tap water was used and eleven weeks during which distilled water was used.

TABLE II

Weekly Figures Showing the Purities of Clarified Juice and Syrup

	Clarified Juice			Syrup				
Week of	Brix	Pol.	Purity	Brix	Pol.	Purity	Diff.	
1925								
Dec. 5...	13.45	11.14	82.83	69.43	57.11	82.3	—0.53	Syrup diluted with tap water
" 12...	13.72	11.42	83.24	69.51	57.70	83.01	—0.23	
" 19...	13.95	11.77	84.37	66.04	55.56	84.13	—0.24	
" 26...	12.96	10.68	82.41	65.98	54.38	82.42	+0.01	
1926								
Jan. 2...	13.85	11.76	84.91	67.98	57.71	84.90	—0.01	
" 9...	13.39	11.47	85.66	66.98	56.98	85.07	—0.59	
" 16...	13.52	11.63	86.02	65.53	56.12	85.64	—0.36	
Average ..	13.55	11.41	84.21	67.35	56.51	84.91	—0.30	Average decrease in purity 0.30
1926								
Jan. 23...	12.38	10.73	86.67	66.92	58.30	87.12	+0.45	Syrup diluted with distilled water
" 30...	13.70	11.94	87.15	66.37	58.10	87.54	+0.39	
Feb. 6...	14.33	12.61	88.00	67.10	59.13	88.12	+0.12	
" 13...	14.21	12.47	87.76	65.30	57.28	87.72	—0.04	
" 20...	14.62	12.85	87.89	67.14	58.81	87.59	—0.30	
" 27...	14.64	12.92	88.25	65.42	57.57	88.00	—0.25	

Mar. 6...	15.07	13.33	88.45	68.60	60.75	88.56	+0.11	
" 13...	14.74	12.95	87.86	67.98	59.81	87.98	+0.12	
" 20...	15.21	13.38	87.97	67.01	58.86	87.84	—0.13	
" 27...	15.13	13.19	87.18	67.63	58.91	87.11	—0.07	
Apr. 3...	14.26	12.37	86.75	67.23	58.46	86.96	+0.21	
Average ..	14.39	12.61	87.63	66.97	58.73	87.70	+0.7	Average for 11 weeks shows an increase of .07 between clarified and syrup.

The above tabulation shows that with the exception of two weeks (ending February 20 and February 27, 1926), the purity of the syrup is very close to the purity of the clarified juice when using distilled water. The average purity of the syrup for the eleven weeks is .07 higher than the purity of the clarified juice.

The decrease in purity during the two weeks mentioned was due to an error in the correction at one point on the Brix hydrometer used during that period.

Conclusion

This investigation has shown that it is essential to use water which is free from dissolved solids in diluting syrup, massecuites, and molasses samples.

Where distilled water is not available, the water used should be tested for dissolved solids, since relatively small amounts will reduce the purity of the sample.

Oxya Velox as a Grasshopper Cane Pest in Hawaii

By O. H. Swezey

This grasshopper, *Oxya velox* (Fabr.), occurs from Japan and China to India, Java and Australia. It reached Hawaii quite a number of years ago, for it was abundant on Kauai and Oahu at the time the Orthoptera of the Fauna Hawaiiensis, by Dr. Perkins, was published in 1899. Dr. Perkins states that in 1897 it had not yet spread to the other islands of the group. The only record of it on Maui, so far, is a small colony in a grassy region in a valley in the makai part of Haiku, found by the writer, August 24, 1918. On Hawaii, the only record is by Mr. Williams in a cane field at Hilo Sugar Company, mauka of Wainaku, September 19, 1925. Just why it has spread so slowly on the other islands is not readily explained. Perhaps it is only in recent years that a few have reached Maui and Hawaii from Honolulu, and have not yet had time to increase and become generally spread.

For the past twenty years, on Kauai and Oahu, this grasshopper has been known to feed on cane to some extent at the edges of fields or along grassy roadsides where they have gone from the grass onto the cane. Young nut grass is a favorite food of the young grasshoppers and it is often in nut grass regions

that they have increased to such an extent as to do noticeable injury on the adjoining cane. At the Experiment Station, some of these grasshoppers are always to be found in the portion of the grounds where nut grass prevails, and often a few, or many, stools of cane have a very ragged appearance from the feeding of the grasshoppers on the leaves.

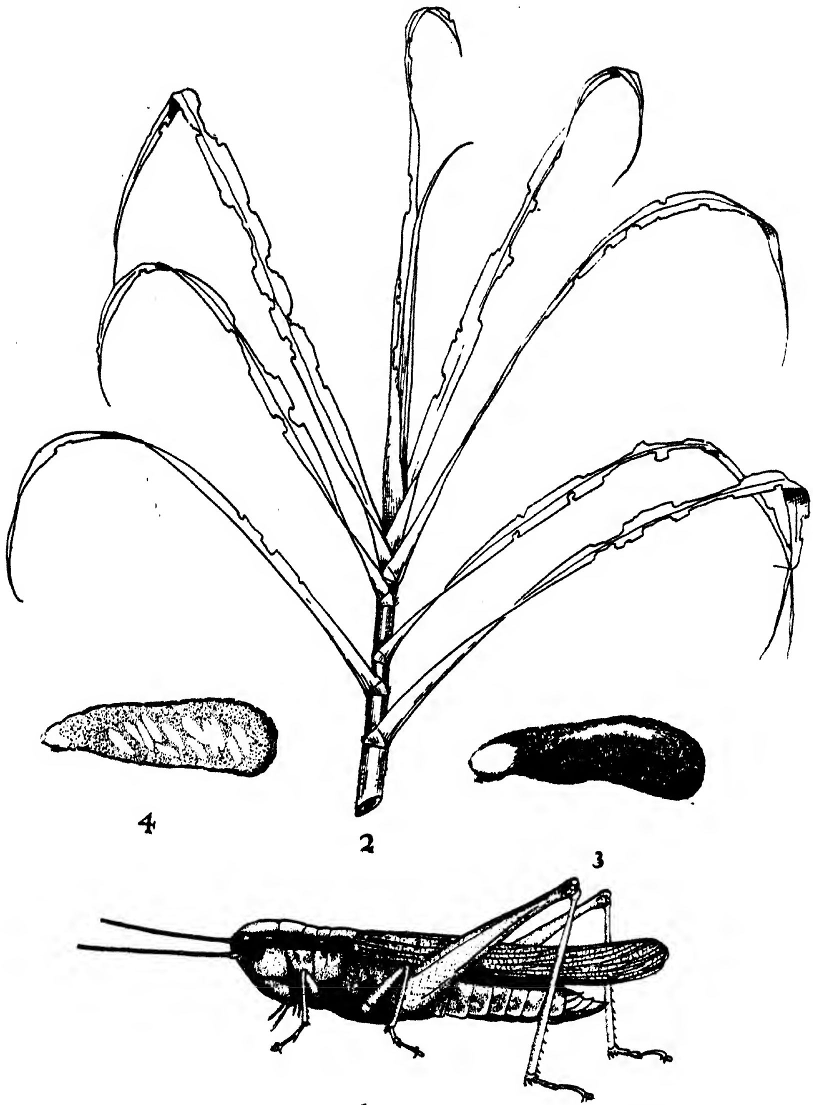
In February, 1924, several acres in a field at Waimanalo had the cane badly eaten, so that all of the upper leaves were very ragged.

For several years past, a colony of grasshoppers has persisted on the grassy roadsides between Fields 10A and 10B, at Ewa Plantation Company, especially toward the eastern end of this road, and the cane at the corner of the field has, at intervals, been noticed to be more or less injured by them. Apparently there has been an increase in this colony, for last year the cane for a wide extent in these fields was considerably eaten by the grasshoppers. On the entomologists' attention being called to it, on their first visit October 30, 1925, many large grasshoppers, chiefly nearly full-grown nymphs and a few adults, were feeding on the cane on both sides of the road and extending for several hundred yards farther into the fields. For a considerable area, most of the upper leaves were ragged from the eating of the grasshoppers and sometimes as many as half a dozen were seen eating on the same leaf.

Numerous small young grasshoppers were feeding on the nut grass of the roadsides and also in the fields, which were very heavily infested with nut grass. Apparently the presence of the nut grass has been an attraction to the grasshoppers as food for the young, from which they have gone up onto the cane leaves as they became half-grown or more. None of the little grasshoppers were observed feeding on the cane, but a swarm of them was raised from the nut grass in walking through it.

When visited a month later, most of the grasshoppers were found to have become matured and many were mating, mostly along the road. After considerable search, a batch of eggs was found. It was slightly below the surface of the soil amongst the nut grass plants. At subsequent visits, more of these egg-masses were found in the banks of nut grass at the edge of the cane field. Visits were made to the place at frequent intervals for a few months and it was found that the number of grasshoppers on the cane diminished and that the newly grown leaves were less eaten and, thus, the recovery of the cane was accomplished, though there must have been some check for a time when the grasshoppers were most numerous on the cane. If the grasshoppers make their appearance quite generally in the nut grass of these fields, when growth starts after the next harvesting, it will be a good opportunity to try the value of poisoning while the cane is yet small enough to allow the operation of spraying or dusting machinery in the field.

Another case of injury by this grasshopper was in cane along a railway in a field just a little north of Hauula on the windward side of Oahu. This place was visited by the entomologists November 9, 1925. At this place there had been considerable grass along the railway. It had recently been cleaned up. Apparently the grasshoppers that had previously been feeding on the grass had



Oxya velox

1. Adult female.
2. Cane shoot eaten by grasshopper.
3. Egg mass.
4. Egg mass sectioned, showing eggs.

gone to the cane and, in several places, their work was conspicuous, though not serious.

Another considerable outbreak of this grasshopper occurred at Honolulu Plantation Company. Attention having been called to it, the place was visited February 19, 1926. A field in Halawa Valley having nut grass along a railway line traversing the field, showed considerable ragged leaves where the grasshoppers had gone to the cane from the nut grass. The injury was chiefly along the edge, not extending inside much, but a few stools were observed at the edge of the field that had most of the leaves stripped to the midribs. This region extended for nearly half a mile along the railroad. As at Ewa Plantation Company, the small young grasshoppers were numerous on the nut grass while the larger nymphs and adults were feeding on the cane leaves.

In November, as it appeared that this grasshopper had increased to considerable importance, and as its life history was very imperfectly known, breeding cages were started at the Experiment Station and maintained for several months to determine definitely the life cycle, etc. The various stages have been pretty well worked out. Single pairs were isolated in separate cages for oviposition and as many as 3 egg-batches per female were obtained at intervals of about a week. Each of these contained about 20 eggs cemented together with a light brownish substance and placed about half an inch to an inch into the soil of the cage used. The records of hatching of quite a number of egg-batches gave a nearly uniform period of 6 weeks. The young grasshoppers grew to maturity in 6 to 10 weeks, there being considerable variation in the time taken. Molting took place at irregular intervals, usually about 10 to 16 days, but sometimes up to 24 days. There were 7 molts, including the one at the time of issuing from the egg, and the final molt when the insects became mature.

Several batches of young were carried through to maturity and then kept until their final death. There was considerable range in this, and no doubt they might have lived longer in the field. In the cages, adults lived from 8 to 12 weeks.

A summary of the life cycle follows:

Egg stage—6 weeks.
Nymph stages—6 to 10 weeks.
Adults lived—8 to 12 weeks.

Thus the total life cycle from oviposition to death of adult grasshopper is 20 to 28 weeks and the length of the feeding period is 14 to 22 weeks. From these data, it is evident that two broods per year are possible and that the 3 to 5 months feeding period makes it possible for them to eat a great deal of grass or cane during a lifetime. Further investigation of the habits and distribution and injury by this pest will be carried on.

The Flowering of Sugar Cane in Hawaii

By Clyde C. Barnum

The breeder of sugar cane is continually striving to obtain, by crossing existing varieties, new seedlings possessing high sugar yielding qualities together with an inherent resistance to certain specified cane diseases. Desirable seedlings must be hardy, must have very good ratooning qualities which lower the cost of production through less frequent planting. Any quality in a new seedling which will decrease the cost of production is essential. In the selection of parent canes for these crosses the plan has frequently been to choose one parent with a very high sugar yield, although having more or less susceptibility to the locally existing cane diseases, and cross this with some well known highly disease-resistant variety. In order to intelligently carry on such work and secure controlled crossing of such desirable characters methods have been devised and certain improvements in the technique have been developed in view of the studies made on sugar cane flowers. Pollen-producing tassels of the desired variety are suspended over the tassels which are to be pollinated and the supposedly cross-fertilized tassel is, after ripening, planted in order to germinate the matured seed. The studies here reported are the observations made during two tasseling seasons in Hawaii and consequently might not apply in other localities under different weather conditions.

In the tasseling season of 1924 the writer observed that certain cane varieties produced apparently viable pollen, other varieties produced little or no pollen; that pollen production of cane varieties was apparently associated with the color of the anthers at or soon after emergence of the individual flowers from the floral envelopes, and that there was a very definite periodicity of flower opening associated with individual cane varieties. The observations made during the tasseling season of 1924 have been more closely followed up during the 1925 season and have materially substantiated the findings of the previous season.

In the literature on the subject of sugar cane flower study Brandes (1)* and Calvino (2) both state that the sugar cane flowers open in the early morning hours. At what hour in the morning the several cane varieties opened new flowers in Hawaii was not definitely known for several cane varieties previous to 1924. In the work of cross fertilizing cane varieties a knowledge of the hour during the early morning when the flowers of each commercial cane variety are opened is of great importance. The period of receptivity of certain varieties may be so late in the day as to preclude the fertilization of the flowers by pollen from earlier flowering varieties unless certain precautions be taken. Certain varieties of cane known to be self-sterile can only be used as female flowers. This work is intended to clear up these points and establish certain definite relations which will be useful in further cane breeding operations.

* **Note: Numbers in parenthesis refer to "Literature Cited."**

Methods Employed in Keeping Tassels Under Observation

The method of Verret, Kutsunai and others (3) for the maintenance of sugar cane tassels in a healthful growing condition in weak aqueous solutions of sulfurous acid was used throughout this work. Cane stalks on which the tassel was just emerging from the sheath were cut in the field and brought into the laboratory with the cut ends under water. These stalks were then placed with the cut ends immersed in sulfurous acid of the correct concentration in individual glass containers. These solutions were changed daily throughout these studies. Tassels so maintained have been kept in a vigorous growing condition for several weeks. The tassels pushed out of the sheath and spread out the branches and spikelets, bearing their numerous flowers, just as growing tassels on the field-grown plants did. During the two seasons, observations have been made on cut tassels in the laboratory with adequate ventilation at all times, as well as out of doors, fully exposed to the prevailing weather conditions. In the absence of rain water on the flowers and tassels the diurnal emergence of new flowers on cut stalks has been found to be identical in tassels kept either inside or outside the building. Rain upon tassels had a deterring effect on anther dehiscence as will be shown later in this paper. For continued observation of individual tassels, only very young tassels were selected and observations begun at the time of emergence of the first flowers. As is usually the case the first flowers to emerge appeared near the tip or distal end of the tassel. These flowers were daily clipped from the spikelets with small shears, or the flowering spikelet was cut back far enough to remove a large number of flowers quickly. The clipping of opened flowers on all tassels was usually done in the late afternoon. Any flowers found open during the following night were, therefore, those flowers which had opened after 4 p. m. of the previous day.

Determination of the Period of Diurnal Flowering of D 1135 Tassels

The initial work on this problem was instituted on November 24 and November 25, 1924, in connection with the problem of determining the hour, or hours, when the most viable pollen could be obtained for artificial germination during a 24-hour period. Observations were made hourly during this period from noon of November 24 to the following noon. For this work 7 tassels of D 1135 cane were maintained in sulfurous acid solution in a sunny room in the laboratory. No light reached these tassels during the night except at short intervals when observations were made, when pollen was taken or when specimen spikelets were taken for microscopic observation. Unfortunately, in view of later work, the initial flowers of six of the tassels under observation had already opened before this test was begun. The tassels were vigorously shaken at the beginning of each hour of the 24-hour test over the three opened Petri dish germinators prepared for that hour and microscopic examination was made later for germinated pollen grains on the 72 plates so prepared. The first exposed plates contained fairly large numbers of wrinkled pollen grains, which failed to germinate, indicating that this pollen had been exposed to dry air several hours and that it had come from the flowers which had opened early on the morning of November 24. Since

this particular study was more closely associated with pollen germination than with flower emergence the hourly observations of flower activities were not as carefully recorded at this time as they were later on when the full significance of flower opening was realized. The fall of pollen decreased regularly during the first 16 hours, but at 5 a. m. the casts of pollen on the Petri dishes were greatly increased in numbers of pollen grains and during the next 5 hours they were distinctly heavy. This heavy cast of pollen followed the heavy flowering which was recorded that night as having occurred and continuing at 3 a. m. An earlier observation recorded at 10 p. m. indicated that flowers were enlarging rapidly within the glumes and by 12 midnight newly opened flowers were first observed on the 7 tassels. The heaviest flowering occurred between midnight and 3 a. m.

On the same date a somewhat similar test was made to determine the period of dehiscence of pollen from a single fresh tassel which had opened approximately one-third of its flowers previous to the beginning of the test. In this test, however, the tassel was not disturbed in the least during the 24-hour period. Each hour a Petri dish was opened and allowed to remain open under the tassel for that interval so that any falling grains of pollen might be caught on the plate surface. The tassel was placed in an upright position in a closed room. Each successive plate was placed in the same spot at each change of dishes. No appreciable numbers of pollen grains were found on any plates exposed previous to 3 a. m., although 4 to 6 grains were found on the 1 and 2 a. m. plates. At 4, 5, 6, 7 and 8 a. m. heavy casts of pollen occurred which germinated extremely well. This test indicated that anther dehiscence began on this particular night at 1 a. m. and that pollen grains were discharged in a viable condition for a period of 7 hours. The heaviest cast of pollen occurred between 3 and 6 a. m. Microscopic study of opening flowers revealed the fact that frequently pollen dehiscence occurred simultaneously with the opening and extrusion of the floral parts. This tendency would make self-fertilization very pronounced in this cane variety.

In support of this suggestion the observations made December 6, 1924, are very strong evidence. The 7 tassels of D 1135 which were under observation were trimmed free of all open flowers the previous afternoon. At midnight no flowers were open on any tassels in this group. At 12:15 a. m., December 6, a flower, in which the floral parts were well extended, was examined under the compound microscope; one anther sac was open and several grains were adhering to the stigmatic hairs. Careful observation indicated that at least one pollen grain had germinated on a stigmatic hair, and the pollen tube had penetrated the stigmatic surface sufficiently to resist gentle tension applied with a dissecting instrument, without rupture of the pollen tube. On 6 tassels heavy flowering had occurred at 1 a. m., and at 2 a. m. practically all well distended anthers were dehiscing turgid pollen grains freely.

Again on December 1, flowers were opening at midnight, yet little pollen was obtained. Very few anthers were open until 4 a. m. and the heavy cast of pollen came at 5 a. m. Self-pollination was observed by 5 a. m. on the stigmas of many flowers.

On these 7 tassels mentioned above, the few initial flowers had appeared on December 3, 1924, at midnight. At 12:30 a. m., December 4, counts were made

of open flowers on several tassels. On tassel No. 1, 30 flowers were open; on No. 4, 23 flowers were open and on No. 7 only 10 flowers appeared. At 2 a. m. the large number of flowers open on these three tassels precluded counting. After 3 a. m. further flower opening was not observed on certain spikelets under observation on which open-flower counts were made. Hourly pollen casts shaken directly into opened Petri dish germinators throughout the same night were heavy only at 1 and 2 a. m. Good germinations were obtained from these plates.

On the same tassels flowering began at midnight, December 5. At 1 a. m., December 6, 1924, pollen was cast freely. Heavy casts of turgid pollen grains were obtained from tassels Nos. 1, 5 and 7, hourly from 1 a. m. to 6 a. m., all of which yielded good germinations of pollen grains.

Again from the same 7 tassels cut December 2, 1924, on December 10, heavy casts of extremely viable pollen grains were obtained at 3:30, 4:30 and 5:30 a. m. On the 9 plates containing pollen obtained at these hours over 120 germinated pollen grains were counted. This would again point to these hours as the best period for obtaining viable pollen under laboratory conditions. No data are available for the earlier hours of the last mentioned study.

On December 11, 1924, a new set of ten D 1135 tassels cut that day and just beginning to flower were put in the outdoor air for a test. All open flowers were trimmed away. No flowers opened previous to midnight. At 1 a. m., December 12, 1924, the first flowers to open appeared on tassels Nos. 5 and 7. Anthers were open at this time on one tassel and not on the other. There were numerous open flowers on 7 of the 10 tassels at 2:20 a. m. No pollen was found on any stigmas at this time. At 3 a. m. flower opening was continued, anther sacs were open, but not dehiscing freely. At 4 a. m. nearly all anther sacs were open and were extruding pollen. Stigmas were almost invariably well covered with plump pollen grains. Pollen was falling freely from the now pendant anthers. Throughout the early morning hours of this test the relative humidity readings were 85 per cent or higher. At 95 per cent relative humidity, the pollen grains remained adhering closely together in the ruptured anthers and were not discharged. Under the microscope these grains appeared very turgid, had particularly moist surfaces and adhered closely to dissecting needles or other objects. Under conditions of lower humidity pollen grains were less adhesive and were more freely discharged from the anthers.

In order to watch the opening of individual flowers under the microscope, an electric light was placed with a flask of cold water interposed between the lamp and the microscope stage, so that the heat of the lamp would not influence the flower activity, and the emergence of new flowers on a horizontally placed living D 1135 tassel was closely watched. A flower was seen to fully open from the first sight of the tips of the floral parts to their full distension in 7 minutes, beginning at 12:17 a. m. and completed at 12:24 a. m., December 11, 1924. Fig. 1 shows a flower in the process of emerging from the floral envelope. Another flower was seen to open the glumes and distend the stigmas fully between 1 a. m. and 1:17 a. m., December 11, 1924. At 2:20 a. m. on over 20 flowers examined, the stigmas were the most prominent of distended floral parts and where the anther sacs could be seen at all they were split open, although no pollen was

Fig. 1. Fully developed flower of D 1135 cane, showing plainly three anthers; two stigmas and the two lodicules at the base of the flower. The ovary lies between the two lodicules. X 25.

Fig. 2. Emerging flower of D 1135 cane. The floral parts are just pushing out of the glumes. X 40.

observed on any stigmas. In Fig. 2 a fully distended D 1135 flower is shown dissected from the glumes. The anther dehiscence is just beginning on these anthers at the distal ends. With further studies on ten D 1135 tassels on December 18-19, 1924, flower opening did not occur until 2 a. m., December 19, 1924, and no pollen was cast until 5 a. m. when most of the anthers were found to be open and pollen was present on the stigmas of such flowers. At no time during the night was the relative humidity higher than 90 per cent and this only at 5 and 6 a. m.

On December 20, 1924, no observations having been made previously, flower opening was not observed until 5 a. m., while at 6 a. m. the splitting of anthers was just commencing. The first record of relative humidity taken that morning was 91 per cent at 4:30 a. m. This percentage remained constant until 8:30 when it fell to 80 per cent. At 6:37 a. m. pollen was found on the stigmatic hairs of these newly opened flowers indicating that dehiscence of pollen had begun.

On December 22, flower opening was in progress at 1:10 a. m. Flower opening ceased at 3 a. m. Humidity readings were relatively low during the early morning; at 12 midnight, the reading was 70 per cent and at 1 a. m., 67 per cent, the highest being 87 per cent at 1:30 a. m.

Throughout these studies in 1924 on the D 1135 tassels it was noted that heavy flowering of any single night was associated with fairly high relative humidity previous to and during the usual period of flower emergence. It was also very apparent on those nights when the humidity was very low that flower opening was distinctly retarded, as well as reduced in relative numbers of opening flowers. On five of the six nights on which flowering was observed throughout the night, flowers were open at 1 a. m.; on one night flowers did not appear until 2 a. m., but on these nights pollen could be obtained by 3 a. m. The heaviest observed casts of pollen occurred between 3 and 6 a. m. under these laboratory conditions.

Effect of Rain Upon Sugar Cane Flowering and Pollen Dehiscence During the Early Morning

Observations in the field and on tassels exposed near the laboratory to outside conditions on several rainy mornings pointed to a deterrent effect on pollen dehiscence induced by rainfall. An experiment was planned to prove this point. Four young D 1135 tassels cut December 6, 1924, were trimmed free of all open flowers on December 7 and put in a cloth cage which could be sprinkled regularly to maintain very high humidity within the cage. The four tassels were placed inside the cage with their cut ends in a bucket of fresh water. The cage and enclosed tassels were sprinkled with a garden hose at the start, 1 p. m., and at 6, 8 and 9 p. m., and again at 3:30 a. m. The water in the bucket was changed frequently during the test. The humidity of the outer air was very high throughout the night of December 7-8, 1924. Table 1 gives the relative humidity of the atmosphere of both the cage interior and exterior. The readings within the cage were taken from a wet-bulb hygrometer and the readings for the exterior were taken by means of a swing psychrometer.

TABLE 1

Relative Humidity and Dew Point Readings Showing Conditions Both Inside and Outside Moisture Cage in Yard at Experiment Station

		Cage Interior Atmosphere		Exterior Atmosphere	
Date 1924	Hour	Rel. Humidity (Percentage)	Dew Point (Degrees)	Rel. Humidity (Percentage)	Dew Point (Degrees)
Dec. 7	1 p. m.	62	68	68	67
" 7	6 p. m.	78	68	84	67
" 7	7 p. m.	91	69	88	67
" 7	8 p. m.	86	68	88	64.5
" 7	9 p. m.	86	68	90	65
" 7	10 p. m.	90	65	93	65
" 7	11 p. m.	85	62	90	62
" 7	12 p. m.	86	62	86	63.5
" 8	1 a. m.	86	64	88	65
" 8	2 a. m.	90	65	90	64
" 8	3 a. m.	90	65	90	65
" 8	4 a. m.	90	65	93	65
" 8	5 a. m.	90	64	95	63
" 8	6 a. m.	90	62	92	62.5

The first observed open flowers were found at 7 p. m. in the cage. At 1 a. m. more flowers were open on one of the tassels in the cage. At 3 a. m. numerous flowers were open in the cage, but of those flowers examined under the binocular only one bore anthers that were open. In this case the anther was split but no pollen had extruded from the narrow opening. No pollen was found on any stigmas. Again at 5 a. m. no pollen was found on stigmas, only a very few anthers were slightly cracked and no pollen was falling. Control tassels kept in the outside air but protected from rain behaved in exactly the same manner. Open flowers were found at 1 a. m. on these tassels and anther dehiscence did not occur until about 6 a. m. Examination of flowers in the cage at 9 a. m. showed many anthers still closed at that time. The very high humidity during the rainy night unquestionably checked anther dehiscence on the exposed tassels.

This experiment was repeated on December 9-10, 1924, using the same tassels in the cage as were used previously, together with 6 control tassels kept in the outer air. The latter were cut December 6. All were in good condition on December 9. All open flowers were trimmed off the tassels before 9 p. m., December 9, 1924. At 12:45 a. m. over 300 new flowers were counted on two tassels in the outer air. At 2 a. m. flowers were still opening and numerous anthers were dehiscing pollen. At 3 a. m. more open flowers were observed than before, anthers were still opening but pollen was not found on any stigmas. At 5 a. m. nearly all anthers were open on all observed flowers on the exposed tassels. Very little pollen was observed on any stigmas. These tassels were not shaken during these observations and as the anthers had opened after emergence from the glumes very little pollen had come in contact with the stigmas. The high humidity also contributed, no doubt, to the slow dehiscence of pollen. In the moist cages on the four tassels enclosed, flowering was in progress from midnight until 6 a. m. At that time no pollen was found on any stigmas observed under the microscope although frequently split anthers were found. This splitting of the anther sacs was attributed to the swelling of the maturing pollen grains within. Pollen grains would be immediately thrown out under drier atmospheric conditions. The anthers remained split open but not dehiscing the enclosed pollen even as late as 8 a. m., December 10, when the observations ended.

It might be a noteworthy observation that in D 1135 tassels under normal conditions the dehiscence of pollen at the time of flower emergence tends to insure self-fertilization at this particular time. On the other hand, when anther dehiscence is held in abeyance by sprinkling the tassels, self-fertilization is very much restricted, since the pollen grains falling from the pendant anthers seldom drop on receptive stigmas. Also when the humidity begins to decrease the relative humidity of the atmosphere may be so low by the time the pollen is extruded that the grains may become shriveled before reaching the stigmas. Especially so in case of bright drying sunlight with dry winds just after sunrise.

A similar test on retarding pollen dehiscence was made on D 1135 tassels the succeeding year. Twenty emerging tassels were obtained December 7, 1925, and placed, two in each of ten cages, with the cut ends immersed in daily renewed sulfurous acid solutions.

Five of the cages were wet from the top as well as on the sides during the early evening hours and again hourly after 3 a. m. throughout each day of the test. The other 5 cages were not intentionally sprinkled throughout the test. All open flowers were trimmed from these 20 tassels in the late afternoon of each day. On December 8 in three of the wet cages no open anthers could be found on the enclosed tassels at 3 p. m. In all the dry cages at this time all observed anthers were open and the pollen had been dehisced.

On December 9, which had been a very hot day, there were still approximately 40 per cent of the newly opened flowers having entirely closed anthers at 9 a. m. In the dry cages at the same hour 100 per cent of the open flowers had anthers fully dehisced. On December 10 at 8:30 a. m. no pollen could be found on the stigmas of the flowers which opened that morning in the moist cages, although a few anthers were slightly cracked open. At the same hour in the dry cages over 50 per cent of the anthers of the newly opened flowers were open. This was a very hot day with a strong breeze prevailing which made moisture conditions in the cloth cages difficult to maintain. At 11 a. m. over 50 per cent

of the anthers were still closed in the wet cages, while 100 per cent were open in the dry cages. These conditions remained fairly constant as late as 3 p. m. On December 11 at noon 50 per cent of the anthers were still closed in the wet cages on the day's open flowers. In the dry cages 100 per cent were open at the same hour. On December 12 careless watering induced identical conditions in both wet and dry cages.

The point seems to be very well established that the effect of water on the tassel actually inhibits the opening of the anthers for several hours after the flower opens. This fact points to a means of controlling crosses between strongly self-fertile cane varieties, in which case even reciprocal crosses could possibly be made on tassels which had been cut and placed under controlled conditions.

Comparative Study of Diurnal Flowering of Commercial Cane Varieties

Observed differences in the flowers of different cane varieties were noted early in these studies. The failure to obtain pollen casts of certain varieties indicated the non-dehiscence of pollen. On such varieties the most easily observed difference in such cases was in the anther coloring after emergence. On those varieties having anthers of an old rose or reddish color, pollen could be obtained. On those varieties having lemon-yellow anthers only, no dehiscence was observed nor could any pollen casts be obtained.

The varieties having perfect flowers, that is, with rose colored anthers, which dehisced pollen normally, were found to be D 1135, Badila, H 109, and occasionally Uba and U. D. 1. Illustrations of dissected flowers of the first four cane varieties can be seen in Figs. 2, 3, 4 and 5. The ovary and stigmas of a H 109 cane flower are shown in Fig. 6. Varieties which have been found to almost entirely, so far as observed, produce lemon-yellow anthers and no viable pollen are: Tip canes, Lahaina, Striped Mexican and Yellow Caledonia. A typical flower of Yellow Caledonia as grown on Oahu is shown in Fig. 7. No anthers are produced, but three stigmas are almost always present in each flower. Uba

Fig. 3. Fully mature flower of Badila cane. The three anthers, two stigmas and two lodicules can be seen distinctly. X 40.

Fig. 4. Fully developed cane flower of H 109. Anthers not yet dehiscing. Stigmas wilted slighted by microscope lamp. X 25.

and U. D. 1 canes could be grouped with these canes were it not for a very rare occurrence of dehiscing anthers. During the tasseling season of 1924, observations were made on several commercial varieties under laboratory conditions and the records, although incomplete, point to varietal differences in flowering activities which have been in part substantiated by the observations made during the season of 1925. These observations were made on 5 tassels of H 109, 7 tassels of D 1135 and a single tassel of Badila in the 1924 season. During 1925 all varieties were represented by 10 tassels, the first lot of tassels being observed under exposed conditions, at times in the rain, while those observed after December 7 were all kept under laboratory conditions. All were cut tassels preserved in sulfurous acid solution, which was changed daily. In Table 2 are recorded the hours of observed emergence of new flowers and dehiscence of pollen of self-fertile canes in both the seasons of 1924 and 1925.

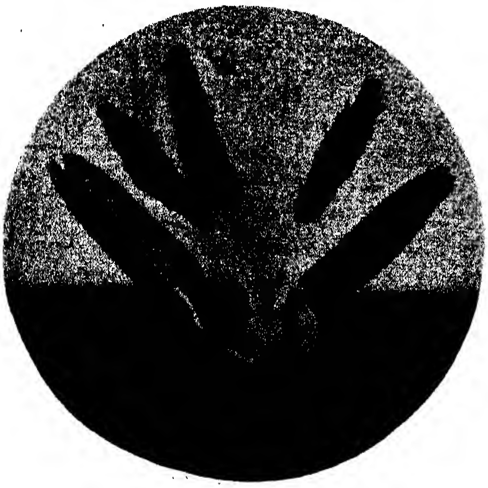


Fig. 5. Fully developed complete flower of Uba cane. The lodicules are distinctly shown at the base of the flower. X 30.

Fig. 6. Stigmas and ovary of a single H 109 cane flower. X 40.

Fig. 7. A typical flower of the 1925 season of Yellow Caledonia, showing the aborted stamens and the well developed stigmas. X 40.

TABLE 2

Flowering Periods of Self-fertile Cane Varieties Observed in 1924

D 1135

Date	Emergence of First Flowers	First Pollen Cast	Heaviest Pollen Cast
Dec. 18, 1924	2:00 a. m.	5:00 a. m.	5:00 a. m.
" 20	5:00 a. m.	5:50 a. m.	
" 22	1:10 a. m.	1:30 a. m.	
" 3, 1925	6:00* a. m.	8:30 a. m.	
" 4	6:00 a. m.	7:00 a. m.	9:00 a. m.
" 5	5:00 a. m.	8:00 a. m.	
" 8	1:00 a. m.	2:00 a. m.	
" 9	3:00* a. m.	3:30 a. m.	
" 10	3:00* a. m.	3:10 a. m.	
" 11	4:00 a. m.		
" 12	2:30* a. m.	2:30 a. m.	
" 13	9:00* a. m.	9:00 a. m.	
" 15	5:00* a. m.	5:00 a. m.	
" 16	5:00 a. m.	6:00 a. m.	

H 109

Date	Emergence of First Flowers	First Pollen Cast	Heaviest Pollen Cast
Dec. 18, 1924	12:00 p. m.	8:00 a. m.	
" 20		8:00 a. m.	8:30 a. m.
" 22	3:00 a. m.		
" 23	12:10 a. m.	1:30 a. m.	
" 2, 1925	5:00* a. m.		
" 3	5:00* a. m.	8:00 a. m.	8:30 a. m.
" 4	5:25* a. m.	9:00 a. m.	9:00 a. m.
" 5	5:00 a. m.	7:00 a. m.	
" 8	1:00 a. m.		
" 9	3:50 a. m.		
" 10	3:30 a. m.		
" 11	5:00 a. m.		
" 12	4:30 a. m.		
" 13	9:00* a. m.		
" 15	6:00* a. m.		
" 16	6:00* a. m.		
" 17	6:00* a. m.		

Badila

Date	Emergence of First Flowers	First Pollen Cast	Heaviest Pollen Cast
Dec. 19, 1924	1:00 a. m.	3:00 a. m.	
" 20	5:00 a. m.	7:00 a. m.	8:00 a. m.
" 22	12:40 a. m.	1:00 a. m.	3:00 a. m.
" 23	12:10 a. m.		
" 12, 1925	3:00* a. m.	3:00* a. m.	
" 14	6:00* a. m.	6:00* a. m.	
" 15	6:00* a. m.	6:00* a. m.	
" 16	5:00* a. m.	5:00* a. m.	
" 17	5:15* a. m.	5:15* a. m.	

* Hours so marked indicate earliest observation made that day.

In studying Table 2 it is noted that certain cane varieties apparently bloomed earlier each morning in 1924 than during the season of 1925. This is not necessarily true, but simply indicates that no one was able to make a 24-hour daily study of the flowers during the latter season. The table does show, however, that flowers are well emerged by 5 a. m. under the usual conditions, even with rain present. On the other hand, rain may so restrain the dehiscence of pollen as to prevent it until 7 or 8 a. m. with certain varieties. Especially is this true with H 109 pollen, which normally dehisces pollen late in the morning.

In Table 3 are recorded the hours of observed flower opening of certain cane varieties which usually do not produce mature pollen grains. Each afternoon all open flowers, together with the supporting spikelet were trimmed from all tassels. All flowers observed during the ensuing night were necessarily newly opened flowers. No tassels of Striped Mexican cane could be obtained during the period of study of the 1925 season.

TABLE 3

Observed Hours of Opening of Flowers of Less Fertile Varieties

Varieties Used

Variety	Date	Hours
Lahaina	Dec. 20, 1924	5:00* a. m.
	" 21	8:00* a. m.
	" 22	12:30 a. m.
	" 23	12:10 a. m.
	" 2, 1925	5:15* a. m.
	" 3	5:20* a. m.
	" 5	6:00* a. m.
	" 8	1:00 a. m.
	" 9	4:00* a. m.
	" 10	3:40* a. m.
	" 11	6:00* a. m.
	" 12	2:30* a. m.
Striped Mexican	Dec. 21, 1924	12:00 p. m.
	" 22	12:00 p. m.
Uba	Dec. 11, 1925	3:00* a. m.
	" 12	3:00* a. m.
	" 15	6:40* a. m.
	" 16	5:40* a. m.
	" 17	7:00* a. m.
Tip	Dec. 19, 1924	1:00 a. m.
	" 20	4:30 a. m.
	" 21	8:00* a. m.
	" 22	3:00 a. m.
	" 23	12:10 a. m.
Yellow Caledonia	Dec. 2, 1925	9:30 a. m.
	" 3	5:00 a. m.
	" 4	9:00 a. m.
	" 7	9:00 a. m.
	" 11	5:20 a. m.
	" 12	4:00 a. m.
U. D. 1	Dec. 9, 1925	4:00* a. m.
	" 10	3:30* a. m.
	" 11	4:30 a. m.
	" 12	2:30* a. m.

The tabulated hours are in many cases not the earliest periods of flower emergence, but the results show that all self-sterile varieties, or those nearly so, are necessarily in a receptive condition nearly as soon as fertile pollen is available from self-fertile varieties. This point is more clearly shown in Table 4, which gives only the hours when open flowers were first noted daily during the 1925 season.

* Hours so marked indicate earliest observation made that day.

TABLE 4

Hours of First Observation of Open Flowers on Cane Varieties During 1925

Date 1925	Lahaina First Observed Open Flowers a. m.	Lahaina First Observed Open Anthers a. m.	H 109 First Observed Open Flowers a. m.	H 109 First Observed Open Anthers a. m.	D 1135 First Observed Open Flowers a. m.	D 1135 First Observed Open Anthers a.m.
Dec. 2	5:15	....	5:00	8:30	....	....
" 3	5:20	....	5:00	8:30	5:30	....
" 4	....	....	5:25	9:00	5:30	(Rare)
" 5	6:00	....	5:30	7:30	5:30	8:00
" 7	9:00	....	....	....	6:00	9:30
" 8	1:00	....	1:00	....	1:00	2:00
" 9	4:00	....	3:50	....	3:30	3:30
" 10	3:30	....	3:40	....	3:10	3:10
" 11	5:30	....	5:40	....	4:00	4:00
" 12	2:30	....	4:40	9:00	2:30	2:30
" 13	9:00	....	9:00	10:00	9:00	9:00
" 14	5:00	....	....	....	5:00	5:30
" 15	....	....	6:00	....	6:30	6:30
" 16	6:40	....	6:25	....	6:30	6:30
" 17	6:40	....	....	....	....	....

Date 1925	Yellow Caledonia First Observed Open Flowers a. m.	Yellow Caledonia First Observed Open Anthers a. m.	Uba First Observed Open Flowers a. m.	Uba First Observed Open Anthers a. m.	U. D. 1 First Observed Open Flowers a. m.	U. D. 1 First Observed Open Anthers a. m.	Badila First Observed Open Flowers a. m.	Badila First Observed Open Anthers a. m.
Dec. 3	7:00	....	....	....	....	....	....	....
" 4	8:45	....	....	....	....	....	....	....
" 7	9:00	....	....	....	....	....	....	....
" 9	....	....	....	....	4:00	....	....	....
" 10	....	....	....	....	3:37	....	....	....
" 11	5:20	....	5:00	....	4:30	....	....	....
" 12	4:15	....	3:00	....	2:45	....	3:00	3:15
" 13	9:00	....	9:00	....	9:00	....	10:00	....
" 14	....	....	....	....	....	....	6:00	6:00
" 15	....	....	6:30	....	7:00	7:00	5:30	6:00
" 16	....	....	5:45	....	7:00	....	5:00	6:00
" 17	....	....	6:00	7:00	7:00	7:00	5:00	5:45

From a study of the periods of open flowers and dehiscing pollen as shown in Table 4, it is readily seen that D 1135 tassels may be used as male parents in crossing with Lahaina because the Lahaina flowers are in a receptive condition in the early hours of the morning, usually by 3 a. m. On the other hand, were H 109 to be used as male parent in a cross of H 109 and Lahaina the late appearance of H 109 pollen each morning would tend, in cases where the tassels were exposed to drying winds and sunshine before that time, to preclude cross fertilization, as the pollen grains would be shriveled before reaching the Lahaina stigmas. Also the possibility of crossing H 109 with Uba or U. D. 1 or Lahaina

would be favored by having the parent tassels growing in an enclosure or location where the direct rays of the sun were excluded until 9 a. m. and where high relative humidity could be maintained equally as late in the morning. Such a provision would tend to insure cross-fertilization and under such conditions the number of cross fertilized, viable seeds would be much greater than under less favorable conditions.

The rapidity of flower opening on young tassels is recorded here for two varieties on which counts of open flowers were made at intervals. The rate of opening of D 1135 flowers is shown in Table 5, while that of U. D. 1 is shown in Table 6.

TABLE 5

Showing Rate of Flower Opening of D 1135 Tassels in the Laboratory

	December 9, 1925				December 10, 1925			December 11, 1925		
	3:30	4:50	6:00	11:30	3:00	5:10	1:30	4:00	7:00	1:30
Tassel No.	a. m.	a. m.	a. m.	a. m.	a. m.	a. m.	p. m.	a. m.	a. m.	p. m.
1	...	...	...	...	...	...	...	...	...	...
2	35	55	100	186	27	57	100	33	72	116
3	15	60	150	229	13	165	197	100	170	171
4	32	...	...	...	14	125	231	200	200	200
5	...	51	100	150	4	124	265	150	200	205
6	4	150	...	170	13	122	154	75	120	125
7	10	160	...	255	9	90	172	160	300	363
8	100	...	...	...	7	75	85	50	90	100
9	4	30	38	56	2	12	25	65	140	141
10	15	35	40	78	2	17	46	50	152	322

The D 1135 tassels used for this test were cut December 7, 1925, and had no open flowers on them at the time they were brought into the laboratory. All open flowers were trimmed from the tassels each afternoon and counted.

It may be observed from Table 5 that flowering of D 1135 tassels is, under Hawaiian conditions, at its height between the hours of 3 and 7 a. m. The counts made on December 11, 1925, at 7 a. m. indicate, when compared with the counts made at 1:30 p. m. the same day, that the opening of flowers after seven o'clock is rare. It is unfortunate that hourly counts could not have been made during these studies. From this table it can be seen that the greatest number of flowers appeared previous to 7 a. m. and that the period between 5 and 7 a. m. is, under normal weather conditions, in the absence of rain, the best period for shaking pollen from D 1135 tassels directly on the female tassels which are to be pollinated. This would tend to insure the deposition of turgid pollen grains on receptive stigmas at that time and the germination of the pollen grains would naturally take place before the early morning sunshine could dry the grains or stigmatic surfaces. On the other hand, the flowers opening after 6 a. m. would be dehiscing viable pollen in protected localities much later in the morning and for crossing varieties which flowered later than 7 a. m. D 1135 pollen would be available even as late as 9 a. m. under such favorable conditions.

TABLE 6

Flowering History of U. D. 1 Cane Tassels

Tassels Cut December 8, 1925

Tassel No.	December 8 No. Open Flowers 4:30 p. m.	December 9, 1925 No. of Open Flowers 4:00 a. m.	5:00 a. m.	6:30 a. m.	2:00 p. m.	December 10, 1925 No. of Open Flowers 3:30 a. m.	5:45 a. m.	2:30 p. m.
1	50	+*	+	+	+	+	+	+
2	200	+	+	+	+	+	+	+
3	0	4	10	10	22	5	36	75
4	16	8	14	21	52	5	9	31
5	50	+	+	+	+	+	+	+
6	0	13	14	15	42	8	21	65
7	50	+	+	+	+	+	+	+

Tassel No.	December 11, 1925 No. of Open Flowers 5:45 a. m.	2:40 p. m.	December 12, 1925 No. of Open Flowers 2:45 a. m.	6:00 a. m.
1	+	+	+	+
2	+	+	+	+
3	24	43	30	+
4	5	28	21	+
5	+	+	+	+
6	28	66	40	+
7	+	+	+	+

In Table 6 the flowering of 7 tassels of U. D. 1 is shown. Tassels 1, 2, 5 and 7 produced so many open flowers on the second day that it was impossible to count them accurately. Tassels 3, 4 and 6, being younger tassels, flowered much more slowly, and the young flowers were counted at intervals as stated. No flowers were removed until late in the afternoon each day. It is noted that the greatest number of flowers appeared after 6 a. m., but with the large number of tassels under study it was impossible to make more counts during the forenoon. This variety of cane is, therefore, in an ideal condition, as far as stigma receptivity is concerned, for cross-fertilization between the hours of 5 and 7 a. m.

Typical Tassels of Commercial Cane Varieties

Some idea of the difficulty in making counts of open flowers on very young tassels may be obtained from the illustrations of typical cane tassels shown herewith. All the figures are one-fifth natural size.

Fig. 8 illustrates a very young D 1135 tassel which flowered but one morning. The small opened flowers may be distinguished on the upper left-hand side of the tassel. No open flowers can be seen on the lower half of the tassel. The reddish color of the open flowers aids in the counting process.

A more advanced flowering stage of cane tassels is shown in Fig. 9. This is a Badila tassel on which the large number of open flowers can be very clearly

* Note:—The plus sign (+) in the above table indicates that the number of flowers open at that time was so great that they were impossible to count accurately.

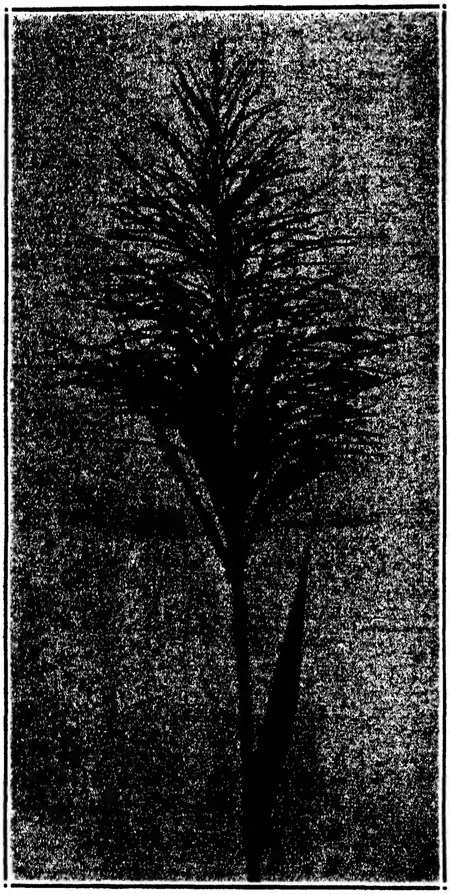


Fig. 8. Early flowering stage of D 1135 tassel. (One-eighth natural size.)

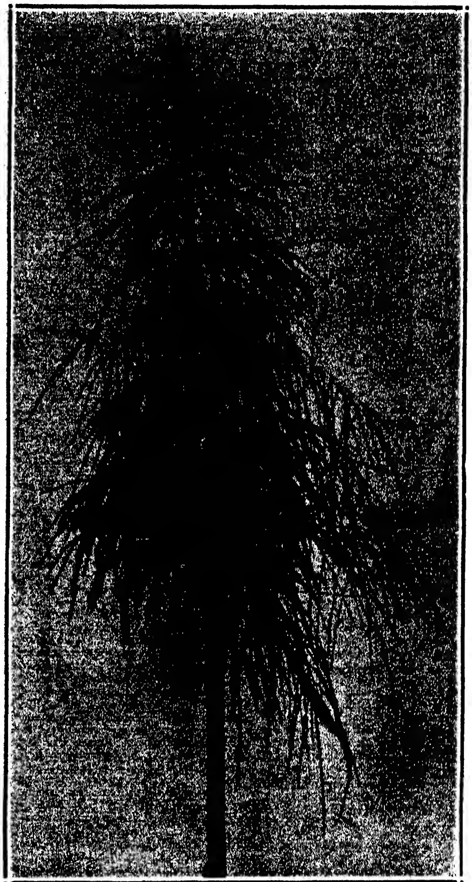


Fig. 9. Late flowering stage of Badila tassel. (One-eighth natural size.)

seen in profile against the gray background. A very difficult tassel to make flower counts on is the H 109, which is illustrated in Fig. 10. The open flowers are surrounded by numbers of bristling hairs which hide the flowers. At the lower left portion of the tassel illustrated, spikelets bearing unopened flowers can be observed. The same characteristics of bristling hairs and compact tassel are typical of Lahaina tassels, as shown in Fig. 11. Here the flowers are even more distinct than on the H 109, due to the bright red color of the stigmas. The large number of open flowers can be seen in this illustration near the left central portion of the tassel. A marked feature of these tassels in our laboratory studies was the tendency to remain partially enclosed in the sheath during the flowering period. This tendency is also noted in H 109 tassels, which shows the inheritance of this character from Lahaina, the female parent of H 109 cane.

A typical Yellow Caledonia tassel is shown in Fig. 12. These tassels were by far the largest under observation and produce only self-sterile flowers. Only a small number of flowers opened on these tassels during the period of observation.

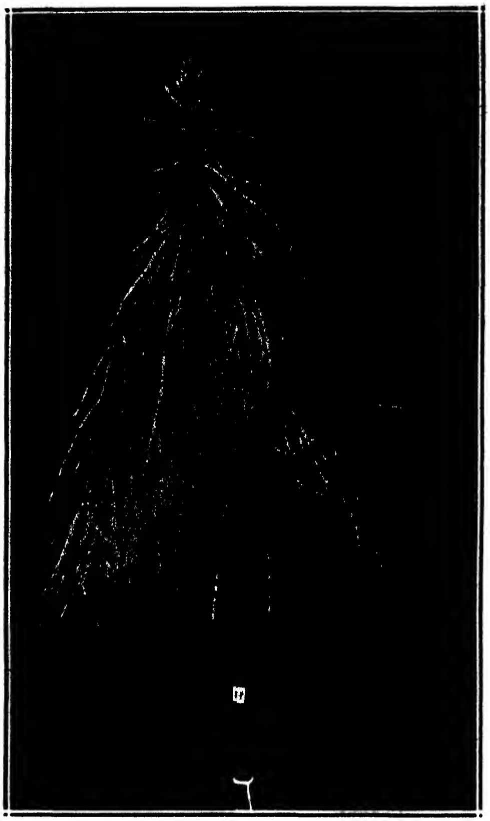


Fig. 10. Tassel of H 109 cane. (One-eighth natural size.)

Fig. 11. Late flowering stage of Lahaina tassel. (One-eighth natural size.)

This variety is usually found with abortive flowers. No open flowers can be distinguished in the illustration. Another self-sterile type of tassel is illustrated in Fig. 13. This Uba tassel usually formed yellow sterile anthers, only a very few of the many open flowers illustrated having dehisced any pollen. The dark spots along the upper spikelets are the red stigmas of the open flowers. These tassels are decidedly whitish as compared to the reddish color of the D 1135 tassels.

In Fig. 14, a tassel of the progeny of a D 1135 and Uba cross is shown. This variety is known as U. D. 1 and the tassel shows the general Uba characteristics, being extremely hairy and of a gray color. The innumerable open flowers are seen at the upper portion of the tassel as dark spots along the spikelets. These dark spots are the protruding stigmas of the open flowers.

To Mr. D. M. Weller, of this Station, is due credit for the photomicrographs accompanying this paper.

Fig. 12. Tassel of Yellow Caledonia cane. (One-eighth natural size.)

Summary

1. Normal flowering of sugar canes is dependent upon high relative humidity, i. e., 80-90 per cent.

2. Rainfall does not hinder flowering but does inhibit pollen discharge as long as the flowers are saturated with water.

3. On both exposed tassels and those kept in the laboratory no flowers were found to open previous to midnight during any night of the study.

4. D 1135 tassels, used in this study as a standard, continued to open flowers from midnight until 7 a. m. each morning during the flowering period of the individual tassel.

5. The greatest number of flowers opening on single tassels during the nights of observation, opened between the hours of 3 and 7 a. m.

6. Heavy pollen casts could be obtained from D 1135 tassels, at 2, 3, 4, 5 and 6 a. m.

7. D 1135 canes are definitely self-fertile. Pollen dehiscence is usually concurrent with flower opening. Single flowers have been found to open, the discharged pollen make contact with the stigmas, germinate and the germ tube penetrate the stigmatic surface sufficiently to resist dislocation with dissecting instruments. All of this occurred within fifteen minutes elapsed time.

8. Self-fertile cane varieties or those having complete flowers with mature pollen grains, are found to be: D 1135, ~~Badila,~~ H 109, and occasionally Uba and U. D. 1.

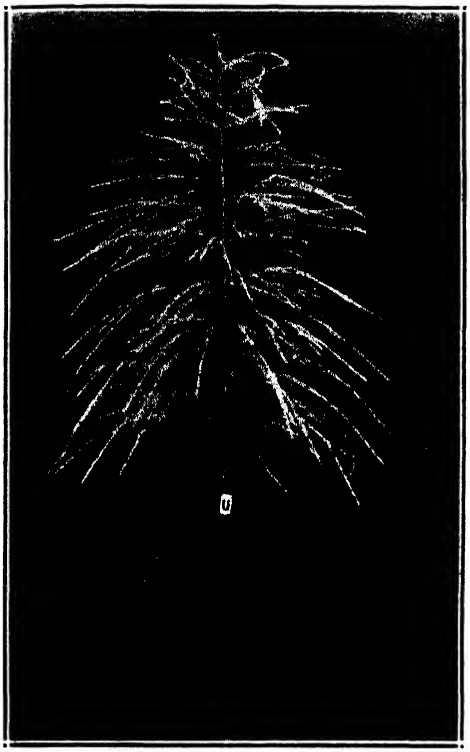


Fig. 13. Advanced stage of flowering of Uba tassel. (One-eighth natural size.)

Fig. 14. Late flowering stage of U. D. 1 tassel. (One-eighth natural size.)

9. Self-sterile cane varieties, or those not having complete flowers, are found to be (usually) Tip canes, Lahaina, Striped Mexican and Yellow Caledonia.

10. The first flowers opening on D 1135, H 109, Badila, Lahaina, Striped Mexican and Tip canes are found between midnight and 3 a. m.

11. Anther dehiscence can be retarded on self-fertile varieties like D 1135 by sprinkling the tassels frequently during the period of flower emergence. In tests made in 1925, 100 per cent of the anthers of flowers opening any particular morning on the sprinkled tassels were restrained from discharging pollen until 9 a. m. Such methods could be adopted to induce crossing of two strongly self-fertile cane varieties.

12. Photomicrographs of sugar cane flowers are shown, as well as photographs of typical Hawaiian-grown commercial cane tassels.

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Progress Report of Sugar Cane Pollen Studies

By D. M. Weller

Knowledge of the amounts of pollen shed, the viability of such pollen, the length of time during which viable pollen is shed, and the environmental factors influencing such pollen formation and viability has a direct and immediate application in the technique of cross-pollinating the various cane varieties commonly used for parent tassels. The knowledge gained by these studies, therefore, places the work of hybridization on a more accurate and precise basis.

Owing to the shortness of the cane tasseling season, approximately from November 1 to December 31, in these Islands, these studies could not be completed in one season and progress will necessarily be intermittent. The following is a *progress report* of cane pollen studies during the 1925 cane tasseling season.

Review of Methods for Determining Viability of Sugar Cane Pollen

Perhaps the method most commonly used for determining the viability of sugar cane pollen is that of applying a solution of iodine in potassium iodide. The resulting bluish-black coloration of the pollen grains following the application of the iodine solution has been interpreted by some to indicate viability, but by others to indicate merely maturity of the grains so colored. Those pollen grains appearing a yellowish-brown color are said to be non-viable or immature. It is now thought, however, that this reaction is not a certain indication of viability. It has been our experience that mature pollen grains which have become dry and wrinkled will not germinate. Such pollen grains, however, show a positive reaction by this method, for they swell in the iodine solution until they become turgid again and show the presence of numerous starch grains which become a deep bluish-black color. Wilbrink and Ledeboer (4) used this method to ascertain whether or not pollen grains of various varieties of cane matured. Mrs. Eva Calvino (2) says that the "presence of starch granules in the pollen grains is not sufficient to indicate conclusively its fertility," and concludes that in addition to the grains being "mature," and "containing starch granules" they must be "morphologically normal."

Germination of cane pollen has been attempted with some degree of success by placing the pollen grains on the stigmatic surfaces of the pistils of various plants, such as papaya and jimson-weed, *Datura stramonium*. At the cane breeding session of the Sugar Section of the Pan-Pacific Food Conservation Conference held in Honolulu, August, 1924, Dr. Mario Calvino told of success in germinating cane pollen by this method. The same method was also in use in Fiji, according to Mr. H. F. Clarke. Dr. E. W. Brandes stated that in Florida the stigmas of the flowers of the moon vine, a species of Ipomea, were being used for this purpose. While germinations of cane pollen have been obtained in this way, the method has the objection that the stigmas of any one of these plants are not necessarily standardized; failure to secure germinations may not be due to the non-viability

of the pollen, but to the character of the stigma used. At the South Johnstone Sugar Experiment Station in Australia (3) the stigmas of Hibiscus were used, but were found "too awkward to handle."

Another method of artificially germinating cane pollen is that of using artificial media, such as agar, sugar solutions, etc. Such germination media can be standardized, thus avoiding the criticism which may be made of the method of using the stigmas of plants. In 1910, Wilbrink and Ledeboer (4) found that pollen of a variety of Chunnee cane germinated "freely on a nutrition plate containing 30 per cent cane sugar and 2 per cent agar, but that of other cane varieties could not be brought to germinate on any nutrition plate." Mrs. Calvino states that she has "obtained germinations of pollen of two varieties by placing them on wheat flour soaked in a 30 per cent sucrose solution. The pollen tubes have reached a length of 88, 99 and 160 microns on such media, but the amount of germination is very low and the results cannot be considered as definite data. It is probable that we cannot obtain germinations in an artificial manner and shall have to be content with an examination of the pollen on the stigmas of the cane flowers." A method in use at the South Johnstone Sugar Experiment Station (3) was to cut a piece of filter paper to fit a microscope slide. A square hole, a little smaller than the size of a cover slip, was made in the filter paper. In this hole the pistils of cane flowers were placed. Pollen was dusted on the stigmas and a cover slip placed over the whole. The chamber thus formed was kept moist by cotton threads attached to the filter paper and leading to a small dish of water. The method was developed further by increasing the number of pistils per slide, but was too tedious to give large numbers of germinations from which to draw quantitative conclusions.

The trials made at this Station in recent years to germinate cane pollen on agar and other artificial media were unsuccessful. Various sugar solutions failed.

In November, 1924, at the suggestion of Dr. F. C. Newcombe, Mr. Barnum secured germinations in Petri dishes, in the covers of which were placed drops of water on bits of filter paper. Although germinations were secured, this method had not been entirely satisfactory because the factors of light, humidity and temperature were not controlled. It was purposed, therefore, to develop a method in which the factors of light, temperature and humidity would be known, thus eliminating all variables except the one of pollen viability.

Attempts to Germinate Pollen at Atmospheric Humidities Controlled by Sulfuric Acid Concentrations

Pollen was shaken from tassels onto cover slips, which were inverted and sealed with vaseline on shell vials with ground tops. These vials were half filled with different concentrations of sulfuric acid solutions which resulted in the air chambers of the vials having relative humidities of 100 per cent, 98 per cent, 96 per cent, etc., on down to 80 per cent, and were placed in a constant-temperature oven, at a known temperature, and light excluded.

On November 12, ten tassels of D 1135 and six of H 109, which had been cut and placed with the cut end in sulfurous acid solution on November 8, were brought into the laboratory. The opening of the flowers and the dehiscing of the

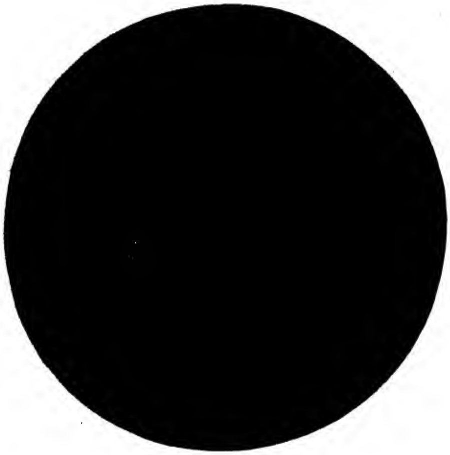

Fig. 1. A dissected cane flower of the variety H 109, showing a dehiscing anther and the mature pollen grains within. Pollen for the germination experiments was collected at this stage of the flowers' opening. X 40.

anthers was observed in order that the tassels might be shaken over the cover slips at the time of the shedding of the maximum amount of pollen (Fig. 1). This time was determined by counting under a binocular microscope the number of dehiscing anthers on branches from different parts of the tassel. When 80 to 90 per cent of the anthers were dehiscing, the tassels were held above a large moist chamber, on the bottom of which the cover slips were placed. By gently rapping on the branches with the handle of a dissecting needle, showers of pollen were discharged from the bursting anthers and deposited on the cover slips beneath. It is obvious that air drafts should be avoided during the process. The cover of the large moist chamber in which were placed from 12 to 15 drops of water on bits of filter paper was quickly replaced. The cover slips on which the pollen was deposited were then taken out of the moist chamber one by one (the cover of the moist chamber being replaced after each one), inverted and sealed on the vials containing the sulfuric acid solutions. One set of vials was immediately placed in the constant-temperature oven at 27.5° C. A duplicate set as a control was kept outside the oven at room temperature. Pollen from the six H 109 tassels was treated identically with the pollen from the D 1135 tassels.

After twelve hours these four sets of vials were examined without removing the sealed cover slips, by placing them individually under a binocular microscope having a magnification of X74. It was apparent from the number and size of the drops of condensed moisture on the cover slips and on the slides of the vials that there was a range of relative humidities in the vials gradually decreasing from 100 per cent on down to 90 per cent, where no moisture was apparent on the cover slips even under 74 magnifications.

The pollen grains also showed evidence of this range, for in the vial of 100 per cent humidity most of the pollen was bursted in the drops of moisture, a smaller per cent was bursted in the drops of moisture in the vial of 98 per cent humidity, and so on down to the vial of 92 per cent humidity, below which point

there were no drops of condensed moisture on the cover slips and the pollen grains were shriveled, evidently from drying. The pollen grains on the cover slips not in contact with condensed moisture were turgid, somewhat swollen, and glistening.

In the set of vials containing the D 1135 pollen at 27.5° C. and the control at room temperatures there were no germinations. The same was true for the set of H 109 and its control at room temperature.

Attempts to Germinate Pollen in Watch Glasses and Micro-Culture Slides Over Sulfuric Acid Solutions

Because no germinations resulted from the trial above it was surmised that the viable pollen was heavier than the non-viable and, being too heavy to stick to the cover slips, had fallen off. The next morning, therefore, November 14, pollen from the D 1135 tassels was dusted into watch glasses, which were set on thick micro-culture slides in Petri dishes. The sulfuric acid solutions were poured into the Petri dishes around the micro-culture slides. Two sets were made with a range of humidity from 100 per cent down to 80 per cent in the same way as with the vials of the experiment above. The covers of one set were sealed with vaseline; those of the other were unsealed. Both were kept at room temperature. Examination after twenty-four hours showed no germinations.

On November 16, pollen from the D 1135 tassels was dusted onto cover slips which were inverted and sealed with vaseline on micro-culture slides, in each of which was placed a single drop of sulfuric acid solution used in the two previous experiments on a small bit of filter paper placed on the bottom of the chamber. Two sets were made. One was placed in the constant-temperature oven at 27.5° C. and the other on the laboratory table where the temperature ranged from 20° C. to 27° C. Examination after twelve hours showed no germinations in either.

This experiment was modified by dipping small bits of filter paper into water instead of sulfuric acid solution, the method described by Badami (1) being used, but with negative results.

Germinations in Petri Dishes With Drops of Moisture Inside Their Covers Used as a Control Method

It was decided, therefore, to use the method of placing moist bits of filter paper inside the covers of Petri dishes as being the best method at hand and to learn why it had not always resulted in germinations; also to develop it so that it could be used as a control on the method described in the first experiment where the factors of light, humidity and temperature were known. On November 17, pollen from the D 1135 tassels used above (cut November 8) was dusted into Petri dishes, the lids of which contained 1, 2, 3, 4, 5, 6 and 7 drops of water. A duplicate set was made with pollen from D 1135 tassels cut November 13. After twelve hours, germinations (Fig. 2) were found in the second set, but none were found in the first set. These germinations occurred in the dish with 5 drops and the one with 6 drops. *Datura* stigmas were placed in Petri dishes and pollen from the second set of tassels shaken over them. Their covers contained

Fig. 2. A germinated pollen grain of D 1135 just before it ruptured. This germination took place in the bottom of a Petri dish in the cover of which were placed five drops of water on small bits of filter paper. X 130.

0, 1, 2, 3 and 4 drops of water. No germinations occurred on the *Datura* stigmas, but germinations occurred on the bottom of the dish having 4 drops of water.

The Relation of Viability of Pollen to the Length of Time Tassels Have Been Cut

Since no germinations had been obtained with pollen from the first set of tassels on the fifth to ninth days after cutting, and germinations were obtained with pollen from the second set on the fourth day after cutting, it was surmised that the obtaining of germinations had a direct relationship to the freshness of the tassels. These tassels were, therefore, discarded and a new set of D 1135 tassels cut on November 18.

On November 19, Petri dishes with 3, 4, 5, 6 and 7 drops of water in their covers were used to catch pollen from the D 1135 tassels cut the preceding day. Germinations resulted in the dish with 5 drops. The temperature was 76° F.

On November 21, the second day, germinations were again obtained with pollen from these tassels in Petri dishes with 5 drops of water. A second set of Petri dishes in the oven at 27.5° C. (81½° F.) showed none.

Ten D 1135 tassels and ten H 109 tassels cut on December 1, on which the first flowers opened on December 2, gave germinations on December 2, 3 and 4.

Ten uniform D 1135 tassels, fully emerged from the sheath, were cut and put in sulfurous acid solution on December 7. Pollen from these tassels germinated as shown in Table I. Each tassel was given a number and germination tests conducted separately for each.

At this stage of the work it was seen that in order to get a comparison of methods, a *quantitative measure* of the germinating pollen must be available. For this reason counts of germinating pollen were made and percentages of germination determined. The total number of pollen grains and the number of germinating pollen grains on ten microscope fields were counted for each tassel.

TABLE I

Showing Decrease in Viability of Pollen on Succeeding Days From 10 Tassels of D 1135 Cane; These Tassels Were Entirely Emerged from the Sheath When Cut

Number of days after cutting tassels	Total number pollen grains on 100 microscope fields	Germinations Number	Germinations Percentage
1	1745	60	3.4
2	2568	41	1.59
3	1196	2	0.16
4	640	0	0.0
5	1314	4	0.3

Ten uniform D 1135 tassels, half emerged from the sheath, were also cut December 7. Pollen from these tassels germinated as shown in Table II.

TABLE II

Showing Decrease in Viability on Succeeding Days of Pollen from 10 Tassels of D 1135 Which Were Only Half Emerged from the Sheath When Cut

Number of days after cutting tassels	Total number pollen grains on 100 microscope fields	Germinations Number	Germinations Percentage
1	365	13	3.5
2	1412	4	0.2
3	432	5	1.1
4	883	0	0.1
5	3111	10	0.3

Ten uniform D 1135 tassels, cut December 5, kept in water until December 7, and then transferred to sulfurous acid solution and brought into the laboratory showed germinations as recorded in Table III.

TABLE III

Showing Results of Germinations of Pollen from Ten D 1135 Tassels Held Two Days in Water Before Transferring Them to Sulfurous Acid Solution

Number of days after cutting tassels	Total number pollen grains on 100 microscope fields	Germinations Number	Germinations Percentage
3	76	0	0.0
4	1335	4	0.29
5	1159	0	0.0
6	1462	4	0.27
7	893	0	0.0

From the results shown in Tables I, II and III, it seemed apparent that with increasing age after cutting, the tassels produced a smaller percentage of viable pollen. This led to the reconsideration of the factors of humidity and other environmental factors for germination, using pollen from freshly cut tassels for such tests.

The Influence of the Factors of Temperature and Humidity Upon Germination of Cane Pollen

In considering further a method of germinating cane pollen it was noted that in the previous trials with the vials of sulfuric acid solutions, the temperature in the constant-temperature oven was 27.5° C. (81½° F.) and that the tem-

perature of the laboratory would change from the minimum temperature of the preceding night from 62° F. or 68° F. to 75° F. by 9 a. m. and rise to 78° F. or 80° F. by noon, according to the recorded readings of the maximum and minimum thermometer in the laboratory. It was further noted that, when germinations had been obtained in Petri dishes, the temperature was recorded as being 68° F. or 70° F. In view of these facts it was decided to try again the sulfuric acid solutions with fresh pollen.

On December 15, pollen from Badila tassels cut the preceding day was used. Three constant-temperature ovens were maintained at 22° C., 24° C. and 25.5° C., respectively. Four sets of vials with sulfuric acid solutions resulting in relative humidities of 96°, 94°, 92° and 90° were made. One set was placed in each oven and the fourth at room temperature as a control. The results are as shown in Table IV. (See also Figs. 3 and 4.)

It is seen from Table IV that at 22° C., the maximum germination was 5.1 per cent at a relative humidity of 96 per cent. At a temperature 2 degrees higher, 24° C., the maximum germination (4.3 per cent) took place at a relative humidity of 94 per cent and that, at a temperature of 25.5° C., the maximum germination (3.4 per cent) took place at a relative humidity of 92 per cent. In other words, as the temperature was increased the optimum relative humidity decreased and as the temperature was increased above 22° C. the maximum percentage of germinations decreased.

On December 16, pollen from five D 1135 tassels cut the preceding day showed germinations as recorded in Table V.

From the tabulations shown in Tables IV, V and VI, it is seen that the results from both Badila pollen and D 1135 pollen were the same, i. e., as the temperature increased the relative humidity, at which maximum germination occurred, de-

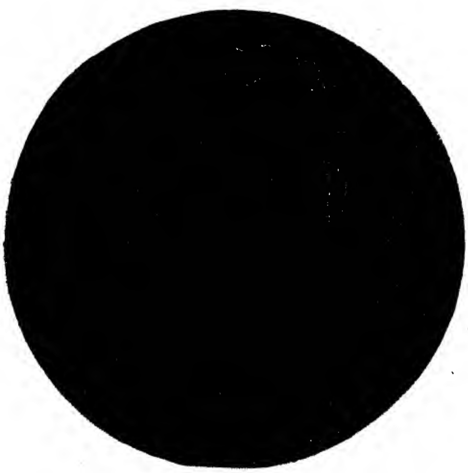

Fig. 3. A germinated pollen grain of D 1135 just before rupturing. This germination took place in a sealed vial of sulfuric acid solution at a relative humidity of 96 per cent and at a temperature of 22° C. Pollen tubes produced under these conditions attained a greater length than those produced in Petri dishes, as shown in Fig. 2. X 140.

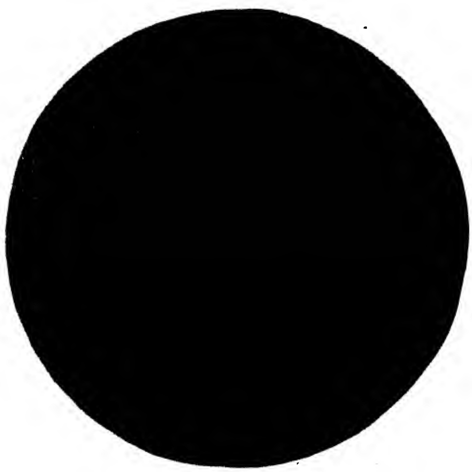

Fig. 4. A pollen grain of D 1135, germinated in the same way as that of Fig. 2, just after it ruptured. X 280.

TABLE IV

Showing Germinations of Pollen From Badila Tassels at Different Temperatures and Humidities: Tassels Cut the Preceding Day

Relative humidity	22° C. No. of pollen grains on 10 microscope fields	22° C. Germination No.	22° C. Germination Percentage	24° C. No. of pollen grains on 10 microscope fields	24° C. Germination No.	24° C. Germination Percentage	25.5° C. No. of pollen grains on 10 microscope fields	25.5° C. Germination No.	25.5° C. Germination Percentage	Vials at room temperature No. of pollen grains on 10 microscope fields	Vials at room temperature Germination No.	Vials at room temperature Germination Percentage
96	251	13	5.1	277	2	0.7	126	0	0.0	266	2	0.7
94	244	11	4.5	250	11	4.3	123	1	0.8	417	0	0.0
92	482	3	0.6	308	10	3.2	204	7	3.4	306	0	0.0
90	331	6	1.8	184	0	0.0	442	14	3.1	462	0	0.0
Total..........	1308	33	2.5	1019	23	2.2	895	22	2.4	1451	2	0.1

TABLE V

Showing the Relative Effects of Temperature and Humidity on Germination of Pollen From Five D 1135 Tassels Cut the Preceding Day

Relative humidity	22° C. No. of pollen grains on 10 microscope fields	22° C. Germination No.	22° C. Germination Percentage	24° C. No. of pollen grains on 10 microscope fields	24° C. Germination No.	24° C. Germination Percentage	26° C. No. of pollen grains on 10 microscope fields	26° C. Germination No.	26° C. Germination Percentage	Vials at room temperature No. of pollen grains on 10 microscope fields	Vials at room temperature Germination No.	Vials at room temperature Germination Percentage
96	366	6	1.6	151	1	0.6	272	2	0.7	199	0	0.0
94	187	1	0.5	266	4	1.5	105	1	0.9	123	0	0.0
92	172	1	0.5	125	2	1.6	206	0	0.0	185	0	0.0
90	204	1	0.4	201	1	0.49	213	3	1.3	84	0	0.0
88	124	0	0.0	179	1	0.55	130	0	0.0	76	0	0.0
Total..........	1053	9	0.85	922	9	0.97	926	6	0.64	667	0	0.0

TABLE VI

Showing the Relative Effects of Temperature and Humidity on Germinations of Pollen From the Five D 1135 Tassels of Table V the Second Day After Being Cut

	22° C.			24° C.			26° C.			Vials at room temperature		
Relative humidity	No. of pollen grains on 10 microscope fields	Germination No.	Germination Percentage	No. of pollen grains on 10 microscope fields	Germination No.	Germination Percentage	No. of pollen grains on 10 microscope fields	Germination No.	Germination Percentage	No. of pollen grains on 10 microscope fields	Germination No.	Germination Percentage
96	196	3	1.5	102	0	0.0	203	0	0.0	168	0	0.0
94	114	0	0.0	274	1	0.3	297	0	0.0	460	0	0.0
92	173	0	0.0	265	1	0.3	366	0	0.0	251	0	0.0
90	143	0	0.0	229	0	0.0	136	0	0.0	177	0	0.0
88	149	0	0.0	147	0	0.0	170	0	0.0	183	0	0.0
Total..........	775	0	0.0	1017	2	0.19	1172	0	0.0	1239	0	0.0

creased; and that at room temperature (approximately 27° C.) little or no germinations occurred. This suggests the existence of an optimum absolute humidity as well as an optimum temperature.

Effect of Carbon Dioxide and Oxygen on Pollen Germination

Since during the hours just before sunrise, at the time of anther dehiscence of cane flowers, and pollen germination, there is usually a heavy respiration of carbon dioxide from the cane plant, the thought occurred that the concentration of carbon dioxide or oxygen in the air might have an influence on pollen germination. To determine such effect, therefore, of carbon dioxide and oxygen on the germination of cane pollen, vials of sulfuric acid solution were used as in the preceding experiments. On December 29, pollen was obtained from a tassel of H 109 cut the preceding day. Through the sulfuric acid solution of each vial in one set, one bubble of carbon dioxide was passed. Through the acid of a second set, five bubbles of carbon dioxide were passed and through the acid of a third set, ten bubbles were passed. To the solutions of a fourth set, five drops of hydrogen peroxide were added; and to the solutions of a fifth set, ten drops of hydrogen peroxide were added. A sixth set untreated was kept as a control over the other five sets. These six sets of vials were placed in the oven at 22° C. The carbon dioxide and the hydrogen peroxide were added to the vials immediately before the cover slips were sealed on the vials and, being heavier than air, would not volatilize into the air quickly. Table VII shows the germinations at the different concentrations of these gases.

TABLE VII

Showing Lessening of Pollen Germination With Increasing Concentrations of Carbon Dioxide and Oxygen

Amount	No. of pollen grains on 10 microscope fields	Germinations Number	Germinations Percentage
Normal air as control	620	12	1.9
1 bubble carbon dioxide	566	4	0.7
5 bubbles carbon dioxide	826	8	0.9
10 bubbles carbon dioxide	495	0	0.0
5 drops hydrogen peroxide	598	1	0.16
10 drops hydrogen peroxide	627	0	0.0

On the second day after cutting, pollen from the same tassel germinated as shown in Table VIII.

TABLE VIII

Showing Lessening of Pollen Germination With Increasing Concentrations of Carbon Dioxide and Oxygen

Amount	No. of pollen grains on 10 microscope fields	Germinations Number	Germinations Percentage
Normal air as control	653	17	2.4
1 bubble carbon dioxide	629	13	2.0
5 bubbles carbon dioxide	554	3	0.5
10 bubbles carbon dioxide	539	0	0.0
5 drops hydrogen peroxide	511	0	0.0
10 drops hydrogen peroxide	148	0	0.0

From the results shown in Tables VII and VIII, it is seen that carbon dioxide and oxygen in the amounts used in these experiments have an inhibiting effect upon the germination of cane pollen. Under the microscope the pollen grains from the vials containing the carbon dioxide appeared to be somewhat darkened while those from the vials containing the oxygen appeared to be bleached.

Trials With Sugar Solutions

On January 2, pollen from a tassel of H 109, cut on December 30, was germinated over sulfuric acid solutions in one set of vials. On the cover slips of a second set was placed one drop of a 10 per cent solution of cane sugar. Both sets were placed in a constant-temperature oven at 22° C. The results of germinations are shown in Table IX.

TABLE IX

Showing the Germinations of Pollen of a Two-day Old Tassel of H 109 in the Presence of One Drop of a 10% Cane Sugar Solution

	Control			1 Drop of 10% sugar solution		
	No. pollen grains	Germinations		No. pollen grains	Germinations	
Relative humidity	on 10 microscope fields	No.	Percentage	on 10 microscope fields	No.	Percentage
100	45	2	4.4	110	0	0.0
98	214	3	1.4	268	2	0.7
96	197	0	0.0	159	2	1.2
94	82	1	1.2	107	0	0.0
92	232	2	0.8	125	0	0.0
90	125	2	1.5	236	1	0.4
88	147	0	0.0	112	0	0.0
Total..........	1042	10	0.95	1117	5	0.44

It is to be noted that the germinations in the second set did not occur in the drops of sugar solution, but in the drops of condensed moisture elsewhere on the cover slips. Apparently this sugar solution had an inhibiting influence on germination. The determining of whether or not this would be true for solutions of other sugars or for solutions of other concentrations of cane sugar will have to be determined at a later date.

The Viability of Pollen from Cut Tassels as Compared With that of Pollen from Growing Tassels

It was next thought desirable to compare the viability of pollen from cut tassels with that of those growing in the field. It was planned, therefore, to test out the pollen of ten tassels growing in the field with that of ten cut tassels. Because of the lateness of the season, these tassels could not be obtained. However, two H 109 tassels were found and used in the following experiment. Since cut tassels have been used so often previously, germination tests were made for two days only with pollen from the cut tassel. Tests with pollen from the growing tassel were made on the first, third, sixth and ninth days. The pollen from both tassels was placed over sulfuric acid solutions and maintained in a constant-temperature oven at 22° C. The results are shown in Table X.

TABLE X

Showing the Relative Germination of Pollen From a Growing Cane Tassel and That From a Cut Tassel at 22° C. and at Different Relative Humidities

A—Growing Tassel

Relative humidity	First Day: No. of pollen grains on 10 microscope fields	First Day: Germinations No.	First Day: Germinations Percentage	Second Day: No. of pollen grains on 10 microscope fields	Second Day: Germinations No.	Second Day: Germinations Percentage	Sixth Day: No. of pollen grains on 10 microscope fields	Sixth Day: Germinations No.	Sixth Day: Germinations Percentage	Ninth Day: No. of pollen grains on 10 microscope fields	Ninth Day: Germinations No.	Ninth Day: Germinations Percentage
100	...	..	....	140	11	7.8	330	18	5.4	50	3	6.0
98	20	3	15.0	140	10	7.1	309	12	3.8	119	5	4.2
96	15	1	6.6	144	4	2.7	334	5	1.1	77	3	3.8
94	17	0	0.0	179	8	4.4	275	3	1.0	62	2	3.2
92	25	0	0.0	87	1	1.1	105	1	0.9	124	2	1.6
90	30	1	3.3	103	6	5.8	327	0	0.0	84	0	0.0
Total.....	107	5	4.6	793	40	5.04	1680	39	2.3	516	15	2.9

B—Cut Tassel

Relative humidity	First Day: No. of pollen grains on 10 microscope fields	First Day: Germinations No.	First Day: Germinations Percentage	Second Day: No. of pollen grains on 10 microscope fields	Second Day: Germinations No.	Second Day: Germinations Percentage
98	191	4	2.0	278	7	2.5
96	144	1	0.6	121	7	5.7
94	177	5	2.8	27	2	2.0
92	41	2	4.8	89	1	1.2
90	67	0	0.0	77	0	0.0
Total.....	620	12	1.9	653	17	2.6

TABLE XI

Showing the Relative Germination of Pollen From a Growing Cane Tassel of D 117 and That From Two Cut Tassels at 22° C. and at Different Relative Humidities

A—Growing Tassel

	First Day			Second Day			Sixth Day		
	No. of pollen grains on 10 microscope fields	Germinations		No. of pollen grains on 10 microscope fields	Germinations		No. of pollen grains on 10 microscope fields	Germinations	
Relative humidity		No.	Percentage		No.	Percentage		No.	Percentage
100	69	2	2.8	56	2	3.5	40	1	2.5
98	73	1	1.3	93	0	0.0	133	0	0.0
96	71	1	1.4	91	0	0.0	39	0	0.0
94	81	2	2.4	77	0	0.0	28	2	7.1
92	34	0	0.0	80	0	0.0	131	0	0.0
90	36	0	0.0	41	0	0.0	33	0	0.0

B—Cut Tassel

	First Day			Second Day			Fourth Day		
100	96	1	1.0	49	0	0.0	162	1	0.6
98	42	0	0.0	79	0	0.0	92	0	0.0
96	175	0	0.0	149	3	2.0	85	0	0.0
94	100	1	1.9	118	0	0.0	72	0	0.0
92	106	0	0.0	102	0	0.0	95	1	1.0
90	61	0	0.0	106	0	0.0	75	0	0.0

Two D 117 tassels cut and placed in sulfurous acid solution and one set cut but growing gave germination results the following day as shown in Table XI.

From Tables X and XI it is seen that the percentage of germination of pollen from growing tassels is much higher than that of pollen from cut tassels, and also that the pollen from the growing tassels is viable over a longer period of days than that from cut tassels. From Table X it is seen that a 15 per cent germination was obtained with pollen from a growing tassel on the first day after cutting. This is the highest percentage of germination obtained during the season. It is also seen that a 6.0 per cent germination was obtained from the same tassel on the ninth day after cutting. This is a higher percentage than was ever obtained from a cut tassel even on the first day after cutting, 5.7 per cent being the highest germination obtained with pollen from cut tassels. From Table XI it is seen that a 7.1 per cent germination and a 2.5 per cent germination was obtained from pollen from a D 117 tassel six days after cutting.

Conclusions

1. Knowledge of the amounts of pollen shed, the viability of such pollen, the length of time during which viable pollen is shed, and the environmental factors influencing such pollen formation and viability has a direct and immediate application in the technique of cross-pollinating the various cane varieties commonly used for parent tassels.

2. Methods for determining viability of sugar cane pollen have not been satisfactory because (1) they do not discriminate between viability and maturity as, for example, the iodine method; (2) they are not adapted mechanically for securing counts in large numbers so that viability may be determined upon a quantitative basis as, for example, the method of using the stigmatic surfaces of various plants such as *Hibiscus*, *Ipomea* and *Datura* and because they are not standardized, i. e., the stigmatic surfaces of these plants are themselves variable and failure of pollen to germinate can be as easily ascribed to the character of the stigmas as to the non-viability of the pollen.

3. Methods of using nutritive media, agar, sugar solutions, etc., are adapted to the securing of quantitative data; in them the contents of the media themselves, temperature and light can be controlled, but because the factor of humidity is uncontrolled, comparative data cannot be secured.

4. The method of using different concentrations of sulfuric acid solutions in sealed vials to secure known humidities is a convenient and satisfactory method of securing quantitative data because the factors of humidity, temperature and light are known.

5. Temperature and humidity have a definite effect upon the percentage of germinations of sugar cane pollen. The optimum temperature was 22° C., at which temperature the maximum germinations occurred at a relative humidity of 96 per cent. If the temperature was raised, the relative humidity at which the maximum number of germinations occurred was lowered, suggesting an optimum absolute humidity as well as an optimum temperature.

6. The percentage of pollen germinations from cut tassels decreases rapidly from 5 or 6 per cent on the first day after the tassel is cut and placed in sulfurous acid to a fraction of 1 per cent on the third or fourth day.

7. A higher percentage of viable pollen is shed from growing tassels than from cut tassels and is shed for a greater number of days. The maximum percentage of viable pollen from growing tassels was 15 per cent, as compared with 5.7 per cent from cut tassels; a 6 per cent germination was obtained with pollen from a growing tassel on the ninth day as compared with a 5.7 per cent germination from cut tassels on the first day, which rapidly decreases to a fraction of a per cent on the third or fourth day.

In conclusion the writer would like to take advantage of this opportunity of thanking Mr. H. Atherton Lee for the idea of conducting these experiments upon a quantitative basis and for his many helpful suggestions. Appreciation is also extended to Mr. R. H. King, of the sugar technology department, for the suggestion of using, and for the preparation of, sulfuric acid solutions prepared according to data compiled by Wilson (5).

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Sugar Prices

96° Centrifugals for the Period March 19, 1926, to June 15, 1926

Date	Per Pound	Per Ton	Remarks
Mar. 19, 1926......	3.975¢	$79.50	Porto Ricos, 3.99, 3.96.
" 20...........	3.96	79.20	Cubas.
" 23...........	3.945	78.90	Cubas, 3.96; Porto Ricos, 3.93.
" 24...........	3.93	78.60	Porto Ricos.
" 25...........	3.96	79.20	Cubas.
" 26...........	4.02	80.40	Cubas.
" 27...........	4.05	81.00	Porto Ricos.
" 30...........	4.035	80.70	Cubas, 4.05, 4.02.
" 31...........	4.05	81.00	Cubas.
April 1...........	4.08	81.60	Porto Ricos.
" 6...........	4.065	81.30	Porto Ricos, 4.05, 4.08.
" 7...........	3.99	79.80	Cubas, 3.96, 4.02.
" 13...........	4.065	81.30	Porto Ricos, 4.08; Cubas, 4.05.
" 15...........	4.125	82.50	Cubas, 4.11, 4.14.
" 17...........	4.14	82.80	Cubas.
" 20...........	4.095	81.90	Cubas, 4.08; Porto Ricos, 4.11.
" 21...........	4.14	82.80	Cubas.
" 24...........	4.195	83.90	Cubas, 4.18, 4.21.
" 26...........	4.24	84.80	Cubas, 4.21, 4.27.
" 28...........	4.18	83.60	Cubas.
May 4...........	4.16	83.20	Cubas, 4.14; Porto Ricos, 4.18.
" 6...........	4.175	83.50	Porto Ricos, 4.14; Cubas, 4.21.
" 7...........	4.21	84.20	Cubas.
" 8...........	4.24	84.80	Porto Ricos, 4.21, 4.24, 4.27.
" 10...........	4.27	85.40	Cubas.
" 11...........	4.255	85.10	Porto Ricos, 4.24, 4.27.
" 14...........	4.14	82.80	Porto Ricos.
" 17...........	4.11	82.20	Cubas.
" 18...........	4.08	81.60	Porto Ricos.
" 20...........	4.14	82.80	Porto Ricos.
" 26...........	4.21	84.20	Cubas.
June 1...........	4.14	82.80	Cubas.
" 4...........	4.125	82.50	Cubas, 4.14; Porto Ricos, 4.11.
" 7...........	4.11	82.20	Porto Ricos.
" 9...........	4.095	81.90	Spot Philippines, 4.08; Porto Ricos, 4.11
" 10...........	4.11	82.20	Cubas.
" 14...........	4.125	82.50	Cubas, 4.14, 4.11.
" 15...........	4.16	83.20	Cubas, 4.14, 4.18.

THE HAWAIIAN PLANTERS' RECORD

Volume XXX. OCTOBER, 1926 Number 4

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Scientific Control of Fertilizer Applications

An account of investigations pertaining to potash applications to the fields of the Ewa Plantation Company is given in this issue by W. P. Alexander. Through work extending over six years, embracing 45 field experiments, 1,000 soil analyses, 1,500 juice analyses, that plantation divides its cane area into six zones in relation to potash applications.

As a result of the work to date, 4,500 acres receive no potash because it is found profitable to leave it off; 800 acres receive extra large applications because yields on these lands respond to such treatment. The remainder of the plantation receives moderate applications because the data in hand indicate that moderate applications are appropriate.

This work at Ewa is a fine example of a thoroughly comprehensive application of science to a plantation problem, not a major problem compared to nitrogen fertilization or irrigation studies, but a secondary problem of sufficient financial importance to merit the attention it has received.

The day of uniform fertilization to all fields of a plantation is gradually passing, as precise information accumulates pointing to the more economical procedure of zoning the area on the basis of actual plant food requirements.

Adventitious Buds or "Node Galls" in Sugar Cane

Three articles on the subject appear in this number: a descriptive article by H. L. Lyon with illustrations of some extreme forms, an article by Kamerling, originally published in Java in 1900, and a progress note by C. C. Barnum, reporting negative results in the attempts to date to infect other canes by injecting the juice of the proliferated tissue.

The type of malgrowth that has appeared on a number of the Uba seedlings and other varieties is interesting but not new. Observations as early as 1914 record instances of it in Hawaii on the stalk, and cases of "bunch top," which is said by Dr. Lyon to be but another manifestation of the same nature, date back to 1910.

We are dealing with one of two things, a condition inherent in the cane itself, resulting in the false growth, occasionally, in many varieties, and rather consistently in certain of the seedlings; or possibly an old and well distributed disease of an infectious nature, to which the great majority of our varieties are highly resistant and to which some of the seedlings are susceptible.

Of the varieties, other than Uba progeny, Makaweli No. 1 shows this excrescent tissue the most, but without the deforming effect upon stalk development noted in some of the Uba hybrids, and quarter-breeds. Of the latter groups the worst of them had better be eliminated for they have small chance to become commercial canes and they are undesirable for breeding purposes. There seems to be no reason to curtail the extension of fairly promising seedlings showing the gall-like excrescences in mild form, for our standard varieties also manifest this trouble in slight degree.

Rat-Damaged Cane

The Honokaa Sugar Company and Pacific Sugar Mill report that after a number of years of intensive poisoning they have succeeded in reducing the rat population of their fields far below their most sanguine expectations. The rat-damaged cane this year amounted to less than one-half of 1 per cent as compared with some 60 to 70 per cent five years ago.

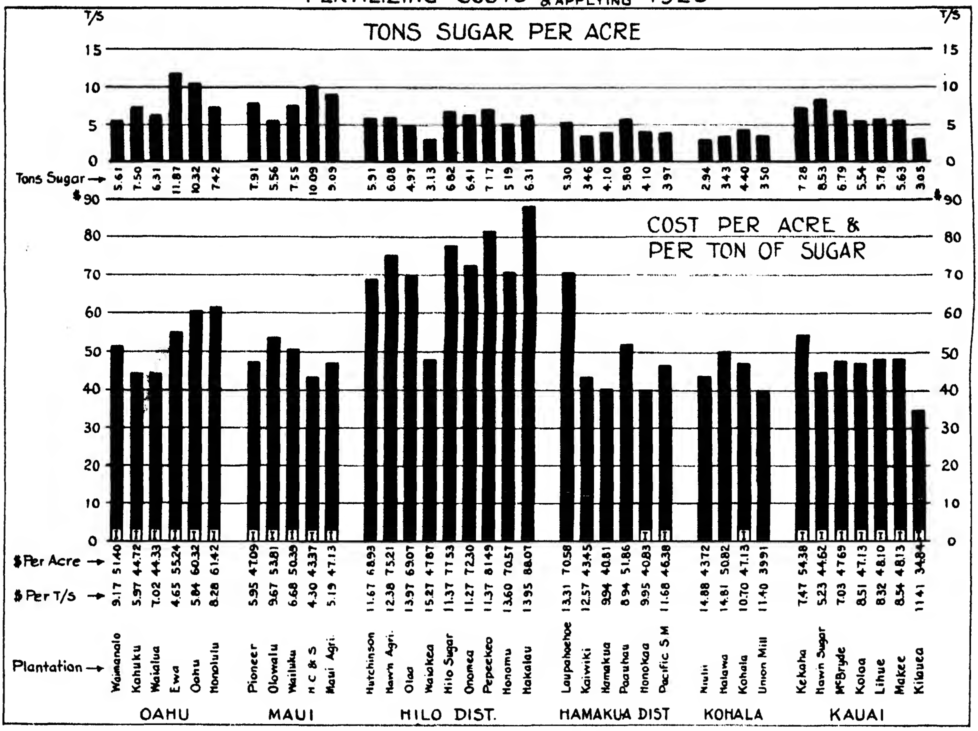
Fertilizer Costs

The accompanying diagram showing fertilizer costs was prepared, originally, at the Hawaiian Agricultural Company, James Campsie, manager. As shown here, the diagram differs from theirs only in that the plantations have been grouped with respect to their geographical location. This comparison of fertilizer costs, per acre, and per ton of sugar, shows in general higher costs per ton for unirrigated lands than for irrigated ones. This difference is due in part, at least, to the better quality of cane in the dry districts. A comparison of fertilizer costs per ton of cane would not show so much variation. Fertilization must be planned with due consideration of probable yield of cane rather than sugar. Three pounds of nitrogen per ton of cane, with nitrogen at 20 cents per pound, amounts to 60 cents per ton of cane. At 7 tons of cane per ton of sugar, we have the cost of nitrogen, unapplied, $4.20 per ton of sugar. At 10 tons of cane per ton of sugar the nitrogen cost would be $6. At 4 pounds of nitrogen per ton of cane the foregoing values become $5.60 and $8 in place of $4.20 and $6.

Phosphoric acid applied at the rate of 60 pounds per acre, at 7 cents per pound, costs $4.20 per acre, to be divided according to yield:

30 tons per acre—14 cents per ton of cane
60 tons per acre— 7 cents per ton of cane
90 tons per acre— 4⅔ cents per ton of cane

FERTILIZING COSTS FERTILIZER & APPLYING 1925



Potash applied at 60 pounds per acre, at 5 cents per pound, costs $3 per acre, to be divided according to yield:

30 tons per acre—10	cents per ton of cane
60 tons per acre— 5	cents per ton of cane
90 tons per acre— 3⅓	cents per ton of cane

Potash is often applied at 100, 150, 200 pounds per acre, and when this is the case the foregoing values are multiplied accordingly.

It would seem, therefore, that the cost of phosphoric acid should average 7 cents per ton of cane and seldom exceed 14 cents; that the cost of potash should average 5 to 10 cents per ton of cane and seldom exceed 30 cents; that the cost of nitrogen per ton of cane should average 60 or 70 cents and seldom exceed 80 cents. Combining these ingredients it is thus seen how there may be a range in fertilizer costs between 72 cents and $1.24 per ton of cane, or, in the event of the omission of phosphoric acid and potash, the minimum might be around 60 cents per ton of cane. Since the tons of cane required to make a ton of sugar on the different plantations vary between the limits of 7 to 11, one can understand a variation in cost of fertilizer per ton of sugar between the extreme limits of $4.20 (7 × 60 cents) and $13.64 (11 × $1.24). Without an analysis of this kind the range of cost of fertilizer per ton of cane as given in the diagram would be somewhat puzzling.

* Hilo district should read Kau, Puna, and Hilo districts.

Available Surface Water*

By Max H. Carson

This subject has been covered in the report of the Honolulu Water Commission made to the Mayor and Supervisors of the city of Honolulu in 1917, much more thoroughly and in considerably more detail than it would be possible for me to cover it in the time allotted to this subject. They made extensive investigations covering a considerable period of time and had at their disposal the services of J. T. Taylor and his engineering staff.

Lorrin A. Thurston, who was chairman of that Commission, has summarized their findings on pages 14 to 29 of their published report, so admirably that there is little more that can be said without the "complete and detailed investigation, survey and report" by an expert hydraulic engineer which they recommend. In general the available surface water is in four classes: (1) Normal flow in the valleys immediately back of Honolulu from Palolo at the one end to Kalihi at the other; (2) Flood water from these valleys and possibly from Moanalua which might be stored in reservoirs; (3) Water which might be collected in ditches along the windward coast from opposite Kalihi north to Waiahole, and brought through to Kalihi in tunnels; and (4) Water which might be collected from Kaneohe south and brought through tunnels to Manoa. Then, of course, there is what we might call a fifth class in the possibility of using water from Waiahole Tunnel.

Taking these various sources up by classes, there is the normal flow from the valleys immediately back of Honolulu for first consideration.

Normal flow is a rather difficult term to define. It certainly cannot mean average flow, for that is made up partly of flood waters. Neither can it mean minimum, although for consideration as a supply for domestic consumption, if no other source were available, it would necessarily approach the minimum. Let us say then that normal flow is an amount which can be depended on for 80 per cent of the time, i. e. that the stream will not flow less than the specified amount more than 70 days a year, or roughly two and a half months.

Then normal flow would probably amount to about 6 or 7 million gallons a day exclusive of Nuuanu which is already pretty well utilized. Most of this water is used for irrigation or is subject to such use so that its use for city supply would require the acquisition of a good many water rights.

The flood waters from these valleys, however, are available provided they can be successfully stored. The average flow of these streams, again excluding Nuuanu, totals probably about 15 million gallons per day. If we assume that 6 million of this is normal flow, it leaves a remainder of 9 million gallons a day available for storage.

* Presented at first annual meeting of Hawaiian Academy of Science, Honolulu, May 19-22, 1926.

This, however, comes in short, sharp floods of very high rates of flow and would require rather large collection works to take care of it all. The streams in Manoa Valley have run at a combined rate as high as 590 million gallons a day for short periods of time. If we assume that we would lose half of these peaks, through inability to catch them, that leaves us 4½ million gallons available for storage. This taken together with the normal flow gives us 10 or 11 million gallons a day additional water available from the streams back of Honolulu.

Mr. Jorgensen estimated for the Honolulu Water Commission that 7½ million gallons a day could be collected in ditches along the windward coast north of Kalihi and brought through the mountains at about 800 feet elevation. So far as I know no more recent records exist that throw any further light on this plan, but I believe Mr. Jorgensen's estimate is a reasonable one.

Any water collected south of Kalihi and brought through into Manoa Valley would have to be collected at lower elevations, but possibly another two or three million gallons a day could be obtained in this manner, at 400 or 500 feet.

These latter projects are, however, limited by the demand that is arising for this water on the Koolau side of the island. Already plans are being made to use more than a million gallons a day of the water Mr. Jorgensen's plan would have diverted to the Kalihi tunnel, for the supply of the Insane Asylum and the communities growing up along the Kailua beaches; and other springs are to be used for the supply of Waimanalo and possibly Lanikai.

Suppose we say then, that we shall have left 4 million gallons a day from that source which might be diverted to Honolulu; we would have available from all these sources combined about 15 million gallons a day that could be counted on.

In this discussion I have, so far, purposely left out of consideration the possibility of developing further supplies in the tunnels that would be necessary to conserve the water I have been talking of. Tunnels, particularly through to Kalihi and Manoa would doubtless develop considerable quantities of ground water as was pointed out in the report of H. S. Palmer to the Board of Supervisors in 1921.

This outline has necessarily been sketchy. To go into more detail, or to express quantities of flow in more exact figures would call for a mass of supporting data and a correlation of plans for conservation that cannot be taken up in the scope of this paper. For instance take the flood mentioned in Manoa Valley when the combined flow of the various branches of the stream was at the rate of 590 million gallons a day for a short period. If the collection works were designed, as suggested in the Honolulu Water Commission report, to catch 50 million gallons a day to be carried to Nuuanu we could get only about 8 per cent of the peak. Twice as large a tunnel would catch 16 per cent of the peak and probably 50 per cent of the entire flood. But this would do little good unless there is reservoir capacity to hold it, and the reservoirs in Nuuanu would be receiving flood water from Nuuanu, and possibly from Kalihi at the same time.

These things require a detailed study, not only of the average amounts of flow, but of the character of the flow, which I believe the Honolulu Sewer and Water Commission is making, and which require continuous records of stage such as are

obtained by water stage recorders. The U. S. Geological Survey, cooperating with the Division of Hydrography of the Territory, has maintained such stations in Manoa, Nuuanu and Kalihi Valleys since about 1911. Stations are now being established in cooperation with the Honolulu Sewer and Water Commission in Palolo and Moanalua to study the character of floods.

In concluding let me point out that all these sources taken together and added to what may be expected from tunnelling will little more than equal what the city is now pumping from the artesian supply, unless we go to Waiahole and thus cripple the plantation it supplies. Hence, if the city grows as we expect it to, we cannot hope to escape the necessity for conservation of what we already have.

The Honolulu Type of Artesian Structure*

By Harold S. Palmer

Geologists define ground water as that water in voids in the rocks which obeys hydrostatic laws. If it exists in sufficient abundance it is recoverable by wells or may discharge naturally as springs, if other conditions are favorable.

In the present connection we may consider two types of ground water: first, ordinary ground water or phreatic water which is not under appreciable hydrostatic pressure; and, second, artesian water which is under enough hydrostatic pressure so that if a hole is sunk into the water-bearing rock (aquifer), the water will rise in the hole to a level above that at which it enters the hole. For use in other connections we could recognize other types of ground water.

It is certain that virtually all of the economically valuable ground water is derived from rain, from melted snow, or from some other form of precipitation of atmospheric water. Two lines of argument lead to this conclusion. It is a valid generalization that regions of abundant precipitation have abundant ground water, and that regions of scanty precipitation have scanty ground water, except where there is a demonstrable underground connection from the dry region to a nearby moist region. It is also a truism that in any given region ground water is most abundant during and after times of abundant precipitation and that ground water is scarce after droughts. The universal coincidence of the abundance of precipitation with the abundance of ground water, both in time and in space, clearly show that ground water for the most part has its origin in precipitation.

The second line of reasoning in proof of this conclusion relates to the composition of ground waters. Juvenile waters, or waters appearing at the surface of the earth for the first time, such as the waters discharged at and around volcanoes, are strongly mineralized. In some parts of the world, such as central

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* Presented at first annual meeting of the Hawaiian Academy of Science, Honolulu, May 19-22, 1926.

Australia, waters travel a very long distance underground and reach great depths. Such waters, by reason of the high temperature and high pressure are particularly able to dissolve a little of the rocks through which they pass and are consequently impregnated with much mineral matter. This high mineralization is also favored by the fact that such waters are in contact with rock for a long time, as their subterranean journey is long. Such mineralized waters, however, are relatively scarce. Most ground waters are low in dissolved mineral matter, which implies that they are derived, and not remotely derived, from some very pure water. The only conceivable source of such pure water is from rain or other form of precipitation from the atmosphere.

Before considering the somewhat unusual artesian conditions at Honolulu it will be well to consider the more usual causes of artesian pressure, and to consider how ordinary ground water occurs in most oceanic islands.

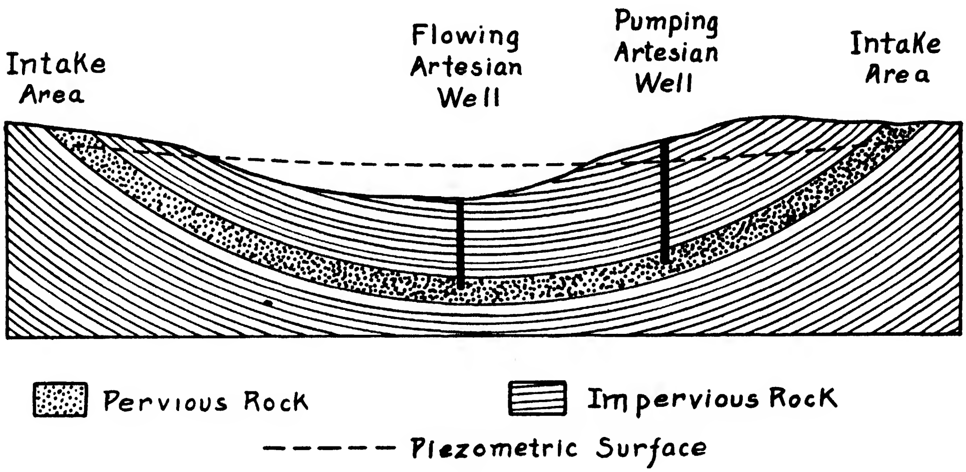

Fig. 1.

The term "artesian basin" is properly reserved for conditions similar to those illustrated in Fig. 1, where there is an extensive bed of rock of such texture that water can readily flow along it. The perviousness of such a rock may be due to an infinite number of tiny chinks between sand grains, to cracks produced by mechanical stresses or to various other causes. The pervious bed has been warped in such a way that edges outcrop at high elevations on all sides of an area in which the bed has been warped down to a considerable depth. The pervious bed is able to absorb water that reaches the high areas of outcrops. This water may be rain or melted snow or ice that has fallen on the "intake area" and soaked in, or it may be water from other regions carried by streams to the intake area.

The pervious bed is overlain and underlain by impervious beds. In many places the impervious rock is one of so fine texture that water is prevented from passing through its voids by molecular adhesion of the water to the walls of the voids. The impervious beds restrain the escape of water from the pervious beds, and thus cause more or less "head" or hydrostatic pressure to develop. The con-

dition is analagous to an imaginary water works (see Fig. 2) in which there are two reservoirs connected by a main pipe. The two reservoirs of Fig. 2 are analagous to the two intake areas of Fig. 1; the hole through the main pipe is analagous to the pervious bed; and the walls of the pipe are analagous to the impervious beds. If the water-bearing bed were perfectly pervious and if the impervious beds were perfectly impervious, water would rise through wells drilled into it and would rise to the same elevation as the intake areas. This would be analagous to the rise of water in various service pipes tapped into the main of the hypothetical water works system. In nature, however, the pervious bed presents considerable frictional resistance to the movement of water through it and the impervious bed is not perfectly impervious and dissipates some of the head by

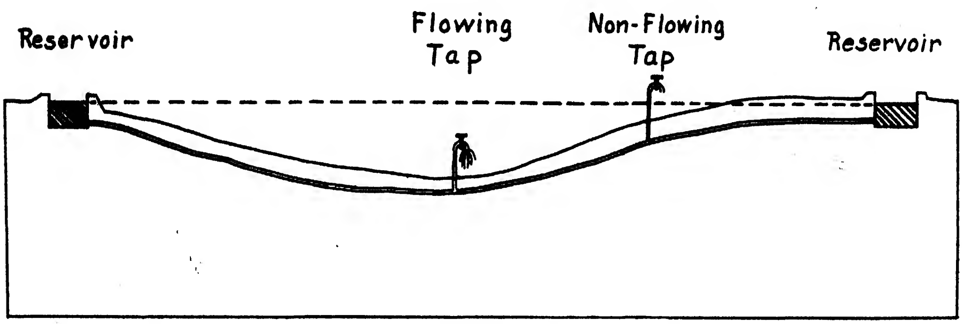

Fig. 2.

letting water escape. Therefore, water will not rise in wells to the same height as the intake areas. It rises to the height of a surface known as the "piezometric surface" (Greek, piezo meaning pressure, and metron meaning measure). Whether an artesian well will flow or will have to be pumped depends on whether the piezometric surface is higher or lower than the ground surface at the point where the well is sunk. Wells illustrating the two conditions are shown in Figs. 1, 3 and 8. The non-flowing or pumping wells are analagous to faucets in the upper stories of high buildings, or on high ground which fail to function at times because of their high elevation.

A more common condition of rock structure than the "artesian basin" is the "artesian slope" in which the pervious bed is inclined in only one direction. This is analagous to the usual sort of water works where the distributing mains lead from a single reservoir. If the main of such a system were open at the distal end the water would escape and little or no water would be discharged at the various service connections. Similarly the distal end of the pervious bed of an artesian slope must be closed in order to prevent escape. Fig. 3 illustrates two ways in which this sealing may be accomplished. In the upper diagram the pervious bed thins toward its distal end with the result that the overlying and the underlying impervious rocks come in contact. In other artesian slopes the texture of the pervious bed changes and becomes impervious, as indicated in the lower diagram. Wells will be failures if drilled at places more remote from the intake area than the point of thinning out or the point of change to impervious, as shown at the extreme right in these diagrams.

The artesian basin, from the geometric point of view, may be considered as two artesian slopes whose pressures oppose one another and prevent the escape of water.

Before considering the causes of artesian pressure at Honolulu it will be well to see how water would be distributed in homogeneously pervious oceanic islands. Fig. 4 is a vertical cross section of an island which consists of rocks of uniform and high perviousness. It is further supposed that this island has no rainfall or other form of precipitation. It is clear that in the course of time sea water will work its way in from the shores and all the voids that lie below sea level will be

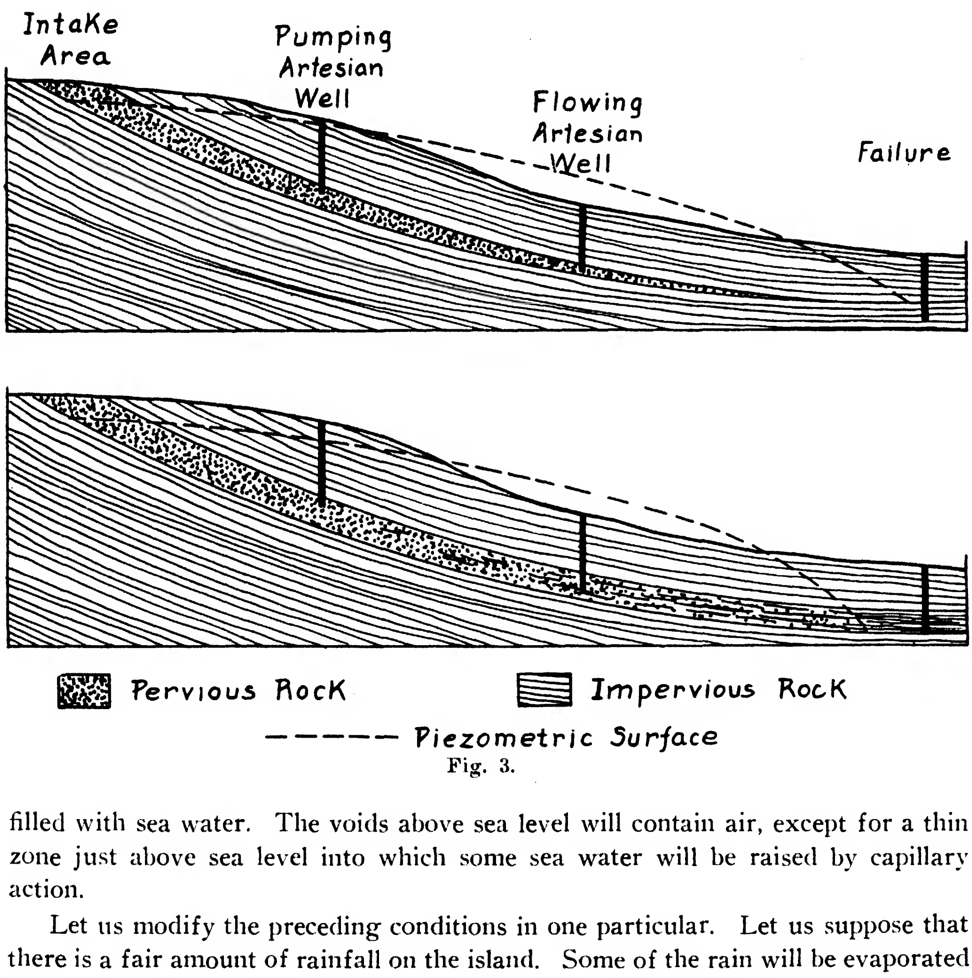

Fig. 3.

filled with sea water. The voids above sea level will contain air, except for a thin zone just above sea level into which some sea water will be raised by capillary action.

Let us modify the preceding conditions in one particular. Let us suppose that there is a fair amount of rainfall on the island. Some of the rain will be evaporated shortly after falling, some will flow off in surface streams, and some will soak into the ground, since the rocks of which the island is composed are pervious. The water that soaks into the ground will move vertically downward in obedience to gravity until it meets some obstacle. In the case of our homogeneously pervious island the first obstacle will be the zone in which the voids are filled with sea water. The fresh water will react in two ways. It cannot displace the salt water completely, because the salt water is heavier and tends to be held in place

by pressure transmitted from the open water along the shores. Therefore, the fresh water will in part move shoreward over the surface of the salt water. This movement will be resisted by interstitial friction and the fresh water will therefore be backed up more or less. Being backed up will cause it to rest on the salt water with more or less weight, thus producing a pressure that will partly counteract the pressure applied to the salt water from the shores. Thus the fresh water will press the salt water downward and to some extent outward. The amount by which the salt water will be depressed depends on how much pressure the overlying fresh water exerts, and this in turn depends on the distance from the shore. The greater the distance from the shore, the greater will be the interstitial friction against which the fresh water must move. The greater the frictional resist-

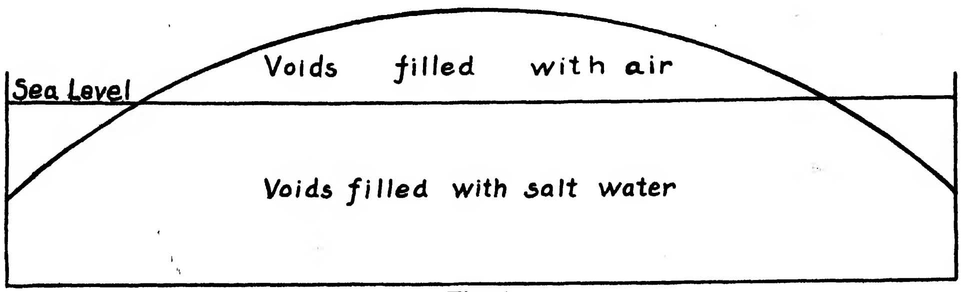

Fig. 4.

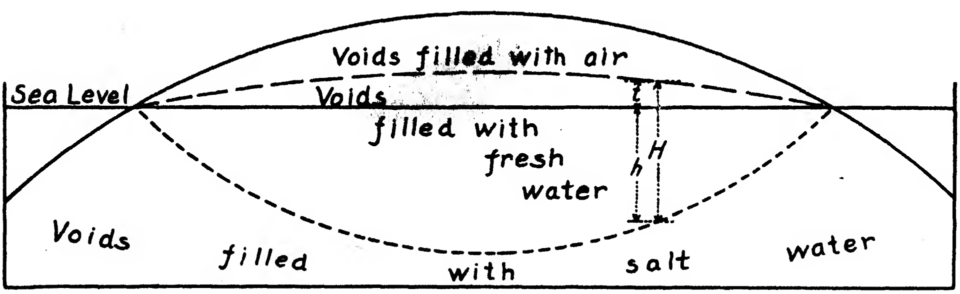

Fig. 5.

ance, the higher the fresh water will be backed up and the greater the pressure it will apply to the salt water. The greater this pressure, the greater the depression of the contact of the fresh with the salt water. Thus there will be under our homogeneously pervious, rainy island the following zones (see Fig. 5):

1. A zone in which the voids are filled with air. (Note: This zone may contain some water that is in transit from the surface downward, having been absorbed only recently.)

2. A zone, shaped like a bi-convex lens, in which the voids are filled with fresh water. The curvature of the lower side of this lens will be much greater than the curvature of the upper side.

3. A zone, extending downward as far as voids exist, in which the voids are filled with sea water.

Since the second zone contains fresh water it is of importance in problems of ground water supply. The thickness of the fresh water lens depends in part on the perviousness of the rock, and is greater in the less pervious rocks. The

thickness also depends on the rate of supply of fresh water and is greater with a large supply of fresh water. At any point the thickness of the part above sea level (t in Fig. 5) is to the total thickness (H in Fig. 5) as the difference in specific gravity of the fresh and the salt water is to the specific gravity of the salt water. If we let g be the specific gravity of the salt water unity, the specific gravity of the fresh water, and h the depth of the fresh-salt transition below sea level, we may write the following equations:

$$H = h + t \qquad (1)$$

$$\text{or } H = hg \qquad (2)$$

whence

$$h = \frac{t}{g - 1} \qquad (3)$$

The sea water around the Hawaiian Islands has a specific gravity of about 1.025, and therefore $g - 1 = 1.025 - 1.000 = 0.025 = 1/40$. Therefore in the Hawaiian Islands the fresh water zone extends about 40 times as far below sea level as it extends above sea level.

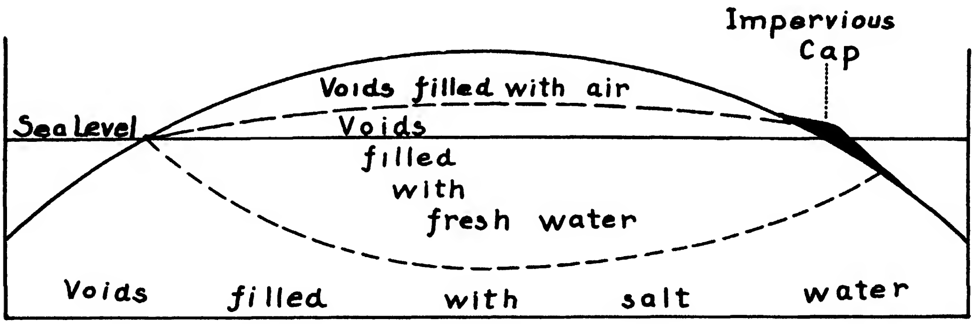

Fig. 6.

The protuberance of the fresh water zone above sea level is due to the fact that the fresh water is lighter than the sea water and floats upon it. Brown* gives a summary of laboratory experiments and of field observations on the coasts of the Netherlands and Germany which shows the validity of this theory, which is named the "theory of Herzberg" after the German geologist who first gave it wide publicity.

In attacking this problem we first considered an island composed of uniformly pervious rocks with no rainfall. We then modified this by supposing the island to have rain. Let us modify the island still further by supposing that there is a capping of impervious rock extending somewhat above and below sea level on the right-hand side, as indicated in Fig. 6. Such a cap would oppose the movement of fresh water seaward, with the result that the fresh water body would have an unusually great thickness beneath the cap and landward from it. It would also prevent escape of fresh water to the sea in a zone extending both above and below sea level. If the cap extended only a little way above sea level but far

* Brown, John S., A Study of Coastal Ground Water, with especial reference to Connecticut: U. S. Geol. Survey, Water-supply Paper 537, pp. 14-20, 1925.

below sea level, the fresh water might be backed up enough so that it would overflow and form springs at the upper edge of the cap. It is probable that the springs along the shores of Pearl Harbor are due to this effect. If the cap extended only a little way below sea level it would produce only a little raising of the fresh water. We may summarize the effect of such a cap by saying that it may hold fresh water up to an elevation above sea level equal to one-fortieth of the depth of the lower edge of the cap below sea level, provided the cap extends this much above sea level.

Let us next consider the conditions at Honolulu. The Koolau Range, back of Honolulu, was built by the pouring out on top of one another of a great number of lava flows. In my opinion, the flows originated from a series of vents along a line that extended northwestward from about Puu Olomana. At all events it is certain that the vents lay to windward of the present Koolau divide, and the lavas flowed to leeward. We are not now concerned with what happened on the windward side, which is a more complex story. The flows tended to fill up any depression that may have been formed in older flows, with the result that a rather smooth cone, similar to the leeward slopes of Haleakala, was formed. In time, volcanic activity ceased, and streams slowly carved radial valleys in the conical slope. Wilhelmina Rise is a piece of the conical surface which has not been appreciably altered by stream cutting. The debris removed by the streams accumulated along the shores, a process that for some obscure reason has not been as effectively followed out elsewhere in Hawaii. The mud of the Waikiki flats originated in this way. Additional matter was laid down along with these streamborne sediments, and included reef-rock made by corals and other lime-secreting animals and also included some volcanic ejecta from Diamond Head, Round Top, Tantalus, and other small craters. The result of all these is a roughly triangular prism of relatively impervious rock, largely mud, clay and coral, which has rather a flat surface. The flat surface includes the part of Honolulu below an elevation of about forty feet, and forms a coastal plain a mile to a mile and a half wide (see Fig. 7).

The lavas beneath the impervious cap are very pervious. The voids in the lava include the following types:

1. Intercrystal Spaces. When cooling and crystallizing the various mineral grains of which the rock is composed may develop minute voids between them. These are too small to be of importance in ground water supply.

2. Shrinkage Cracks. In cooling a lava flow must shrink. This causes tensional stresses in the rock, which result in cracking. These cracks are in general roughly vertical, that is, they are parallel to the shortest dimension of the flow, the thickness. These cracks may be minute or of fair size. The larger ones are effective water carriers because they extend a fairly long distance.

3. Gas Pores. Live lava consists of a complex solution of liquid rock and gases. These gases, on being set free, make bubbles. In extreme cases the lava may resemble a frozen froth or foam. The lavas at Honolulu vary greatly in the abundance of gas vesicles. Where the vesicles are of fairly good size, are abundant, and connect with one another they may transmit a great deal of water.

4. Clinker Voids. When an "aa" lava flow is in motion the chilled and brittle crust is dragged along by the viscous lava beneath. The crust is broken by this drag into extremely rough and irregular pieces. Since these pieces or "clinkers" do not fit together, there are large voids between them. These are very effective in carrying ground water.

5. Bedding Voids. When a later flow is poured out over the irregular surface of an earlier flow, it is impossible for the two to come into perfect contact. The younger flow would have to be very fluid to fit itself to the irregularities of the older flow. But a flow advances over a sort of pavement that it has laid down for itself consisting of its own chilled, solidified and shattered crust. Such voids may be made between the successive batches of lava that are discharged in a

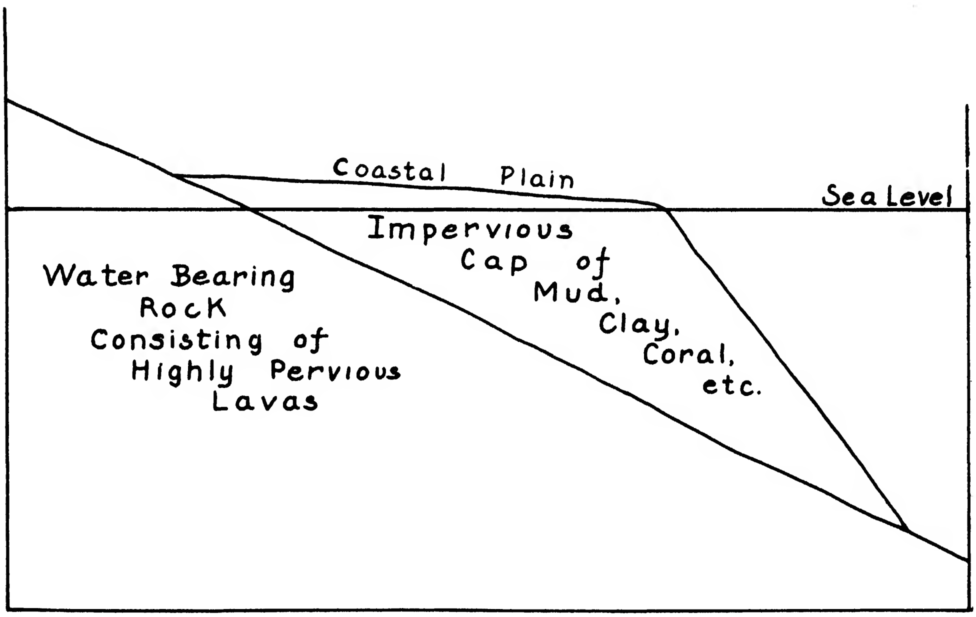

Fig. 7.

single short spasm of activity as well as between flows made a long time apart. Bedding voids are probably the most effective carriers of ground water in the Hawaiian lavas, for they are not only very abundant, but are also very open so that they present little frictional resistance to the movement of water. Moreover, bedding voids may form pervious zones that extend great distances.

6. Subsequent Cracks. Should the lavas, after coming into place and solidifying, be subjected to mechanical stress they may be cracked. Such stress might be due to jarring by earthquake waves, to faulting, or to settling. Subsequent cracks are fairly extensive and may or may not be open enough to carry water.

7. Lava Tubes. Many lava flows develop a hard crust by the cooling and solidification of the upper surface. Later the supply of lava for the particular flow may cease and the liquid lava stream may drain out leaving a long tubular opening under the crust. Lava tubes formed in this way would be as good as artificial pipes for carrying water.

8. Tree Molds. Where a lava flow invades a forest it may kill but not burn up some of the trees. The lava sets around the charred tree, and forms a tube when the tree finally rots away. These are not of importance in the matter of ground water supply.

From the preceding inventory of the openings in lava rocks it is clear that these rocks are highly pervious and constitute a splendid water-bearing rock mass. As indicated above, in the neighborhood of Honolulu, a capping of relatively impervious mud, clay, coral, etc., overlies the highly pervious lava rocks. The thickness of cap rock through which it is necessary to drill in order to reach the pervious rocks varies from place to place. In general it is greater near the shore and less inland because of the general slope of the pervious rocks. Other irregularities are due to the fact that the streams that eroded the original volcanic slope cut valleys at a time when Oahu stood at a higher level than it does now. These valleys have been more or less filled with material like that of the coastal plain. If a well is started at a point overlying such a buried valley, it will obviously be necessary to drill farther to reach the lava rock than would be the case with a well placed otherwise. An example of this was found in the recent drilling of new wells at the Kalihi pumping station.

The abundance and distribution of ground water depend on three factors over which man has virtually no control: the structure of the rocks, the force of gravity, and precipitation. Precipitation provides the water, gravity drives it, and rock structure determines in what direction it will move and where it may be stored.

Rain falling in the region back of Honolulu in part sinks into the ground, and moves vertically downward until it is close to sea level. Then it tends to move seaward, part of it toward Honolulu and part of it toward Kailua (see Fig. 8). The part that moves toward Honolulu meets with the obstacle formed by the

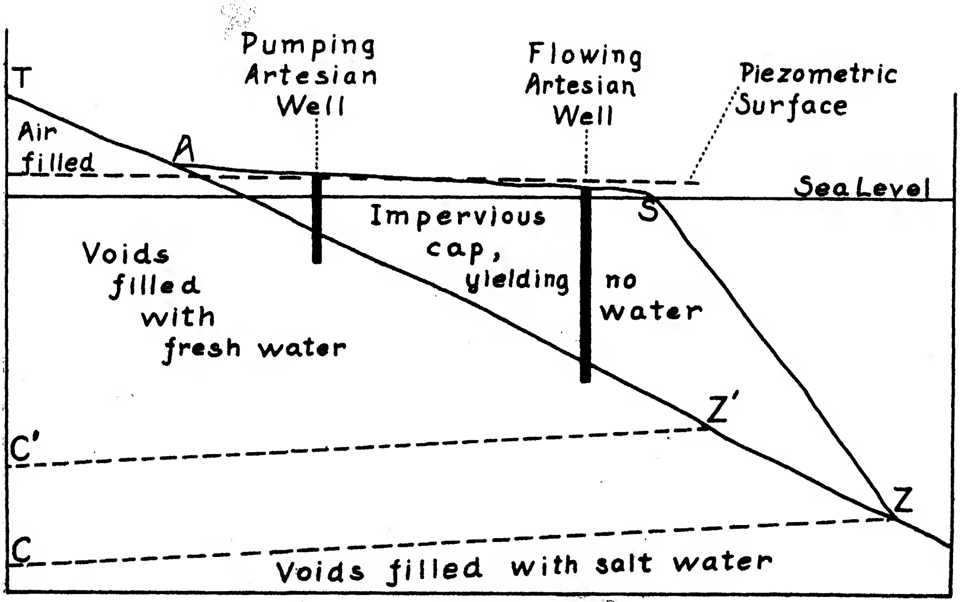

Fig. 8.

impervious cap, and, according to the principle of Herzberg, is backed up. A well drilled down through the impervious cap and into the highly pervious lava rock beneath will enter a zone in which the voids are filled with water. Since the cap extends up to a moderate elevation and since there is in general an ample supply of rain in the intake region the thickness of the body of fresh water held back by the Herzberg principle is great. It was originally about 1,700 feet thick. At the bottom of the well the water will be under the pressure appropriate to the amount it is lower than the upper surface of the zone in which the voids are filled with water. (This pressure is usually expressed as a "head," that is, as the number of feet depth of water necessary to produce the pressure in question. "Head" may be converted to pressure in terms of "pounds per square inch" by multiplying the number of feet of head by 0.434.) As a consequence of the pressure the water will enter the well at the bottom and rise to such an elevation that its weight will produce a downward pressure that will just balance the upward pressure at the bottom of the well. This elevation will, of course, be the same as the elevation of the upper surface of the region in which the voids are filled with fresh water, less a small amount due to reduction of pressure by friction as the water flows seaward through the rock openings.

It happens that the seaward part of the cap at Honolulu is only a little above sea level though the inner edge is rather higher. The seaward edge of the coastal plain is lower in elevation than is the upper surface of the zone in which the voids are filled with water. A well drilled in the seaward region through the impervious cap will enter lava rock in which the voids contain water under a pressure appropriate to a depth greater than that of the well. Consequently such a well will be a flowing artesian well, the rate of flow depending on various factors, one of the most important of which is the difference in elevation between the mouth of the well and the piezometric surface or upper surface of the zone in which the voids are filled with fresh water.

When the first artesian wells were drilled in Honolulu, in 1880, the water rose about 42 feet above sea level. This would imply that the fresh water zone extended about 1,700 feet below sea level. ($42 \times 40 = 1680.$) This 1,700 feet depth is diagrammatically shown as the line C-Z in Fig. 8. Due to the diffusion of salt and fresh water into each other, the contact is a zone of considerable thickness. The artesian head is due to a number of causes, one of which is the more or less complete prevention of seaward escape of water. Various ways in which escape may be retarded have been described, but it may be well to emphasize at this point the concept that at Honolulu the action tending to prevent seaward escape is the back pressure due to the denser sea water. The effectiveness of this back pressure has been partly counteracted by the artificial opening of many channels of escape through the impervious cap. These artificial openings are the many artesian wells. The action is somewhat similar to that which we experience in houses which are served by a single connection to the public water main but which have a number of faucets. The more faucets there are in use, the less the pressure at any one faucet. The analagous proposition is: The more artesian wells there are in use, the less the pressure at any one artesian well.

The head of the artesian water has steadily decreased. The best records are those that have been kept at the Oahu College (Punahou School) well which are graphically shown in Figs. 9 and 10. Fig. 9 shows the variation of the monthly average head for the eight years from 1910 to 1917, inclusive. During this period the head fluctuated so that at its greatest it could raise water in the well to an elevation of 32.5 feet above sea level. In 1914 and 1915, it dropped to 27.8 above sea level. Early in 1916, it rose again to about 32.4 feet as a result of excessively heavy rains in November and December, 1915, and January, 1916. These three months totalled 38.22 inches of rain at the Honolulu Weather Bureau, which is 3.2 times the mean (11.96 inches) for these months. It will be noticed that in each of the eight years shown in Fig. 9 there was a maximum head sometime during the first four months, that is after the water of the rainy season had had time to percolate through the rocks and reach the artesian system. Similarly the minimum in each of the eight years occurred between August and November, that is after the dry season when there was little recharge and a large draft for

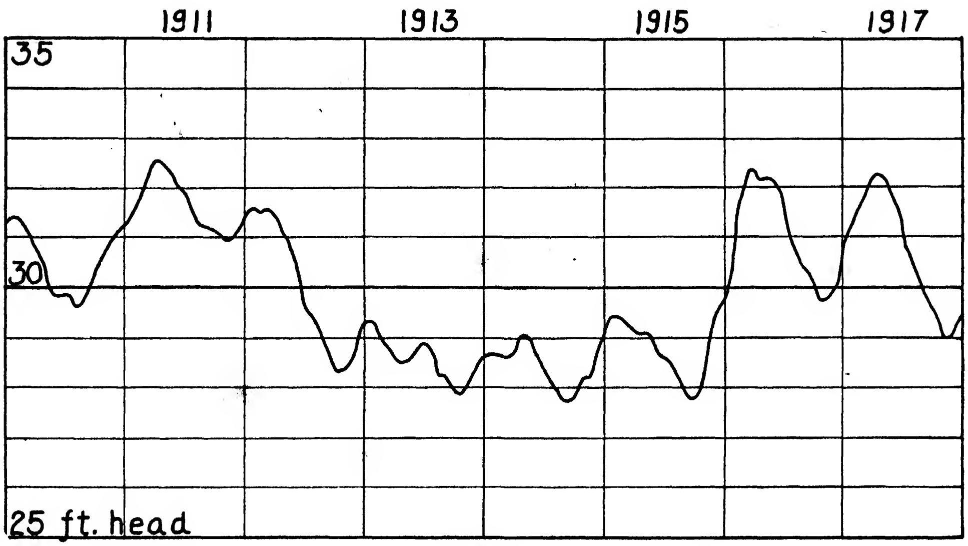

Fig. 9.

irrigation. The artesian head depends not only on the back pressure of the sea water but also on the rate of supply of water from the intake area. This is only one of many examples that show how the local rainfall is reflected in the artesian head.

Three lines are shown in Fig. 10, which relates to the head at the Punahou well from 1888 to 1925, inclusive. The upper line shows the highest monthly average head recorded each year, and the lower line shows the lowest monthly average head. Data are lacking for the four years from 1905 to 1908, inclusive, and the dotted portions indicate heads computed from rain measurements.* The smooth curve is a generalized average and shows the effect of a continued draft

* G. K. Larrison, Arthur G. Smith, and T. F. Sedgwick, Report of the Water Commission of the Territory of Hawaii, Appendix, Fig. 2, Honolulu, 1917.

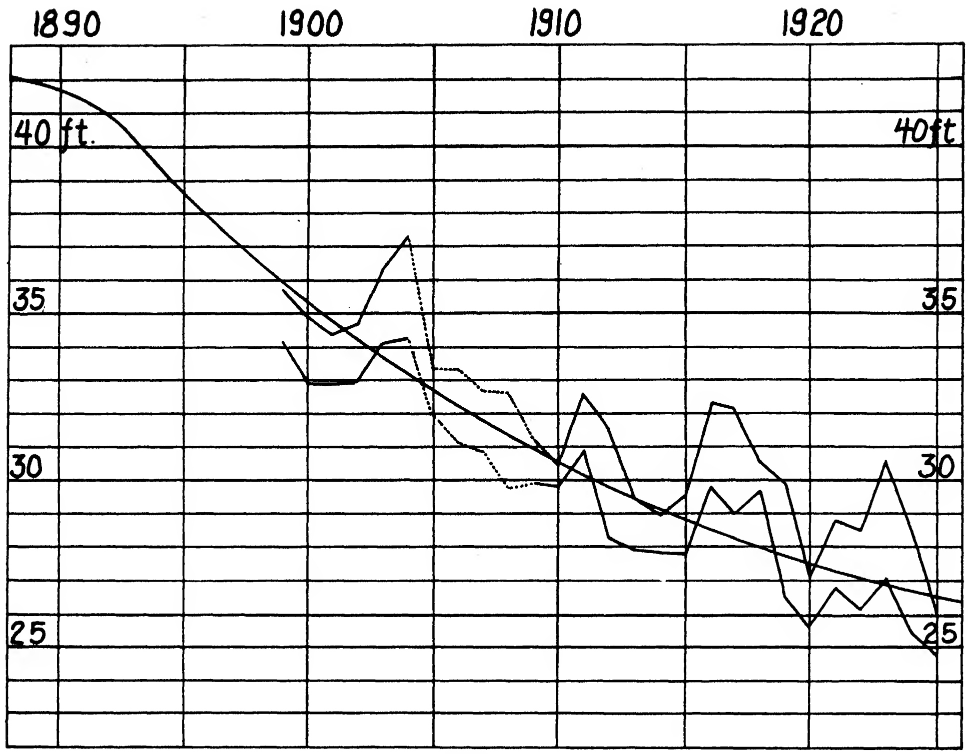

Fig. 10.

on the artesian water-bearing rocks greater than the rate of recharge by absorption in the intake area. At the end of 1925, the head had fallen to a little less than 25 feet. This means that the contact between salt and fresh water has risen from a depth of 1,700 feet below sea level in 1880 to a depth of only 1,000 feet. The new higher level of the contact zone is diagrammatically shown by the line C′-Z′ of Fig. 8. The contact has already risen as high as the bottom of some of the deepest wells and these wells now yield brackish or salt water. Unless overdraft on the artesian supply ceases we may feel sure that more wells will "go salty."

Exotic Trees in Hawaii

By H. L. Lyon

Enterolobium cyclocarpum: This magnificent tree is native in Tropical America and the West Indies. It is known to the outside world principally through the exportation of its timber from Mexico and Central America. Its common names are legion in the countries where it grows and its timber is known in the trade under the names Genisero or Jenisero, Mexican walnut and South American walnut. Many of the names applied to this tree by the aborigines

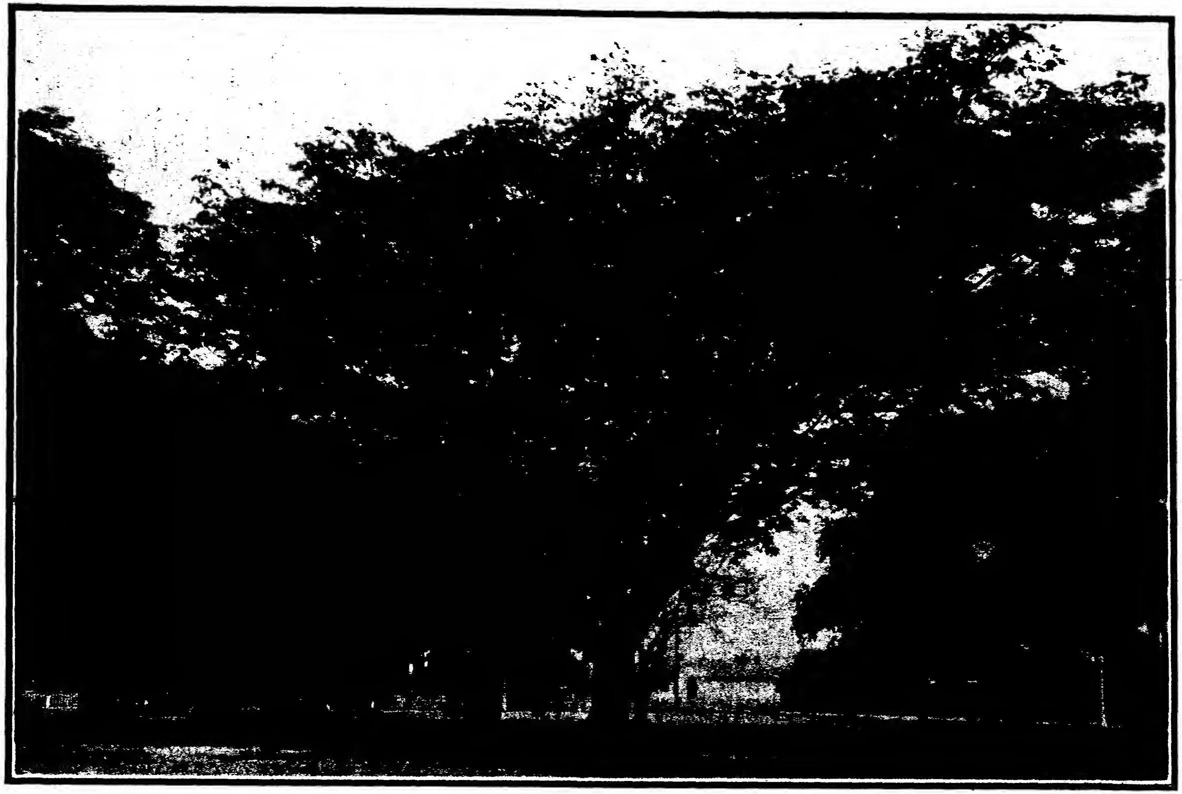

Fig. 1. *Enterolobium cyclocarpum.* A moderate sized ear-pod tree growing in Thomas Square, Honolulu.

Fig. 2. Leaves, flowers and fruit of the ear-pod tree.

refer to its curiously shaped pods, which resemble the concha or external portion of the human ear. In Hawaii, the tree is popularly known as the Ear-pod and Elephant's ear.

Enterolobium cyclocarpum is a rapid-growing tree with up-standing branches, which carry its broad crown to great height. Its leaves are twice pinnate, the ultimate divisions being very small, oblong leaflets, which are extremely numerous; sometimes as many as 2,000 to the leaf. Its abundant, finely divided, feathery foliage, held so far aloft by strikingly massive branches, gives this tree an air of grace and grandeur not possessed by any other tree in our gardens.

The Ear-pod must have been introduced into these Islands some sixty or seventy years ago, judging by a few huge specimens to be found in old gardens. It has never been planted extensively, however, for there are comparatively few old trees in the Territory. The largest specimen with which we are familiar occurs in Mrs. Foster's garden on Nuuanu Avenue. This tree is over 80 feet tall and its trunk measures 21 feet, 7 inches in circumference, 3 feet from the ground. Another large specimen may be seen just off Keeaumoku Street in the grounds of the Board of Agriculture and Forestry. Its trunk measures 15 feet in circumference, 3 feet from the ground and its far-flung branches extend clear across Keeaumoku Street. There are two fine, but younger, specimens in Thomas Square, one of which is shown in an accompanying illustration. The largest number of Ear-pod trees which we have encountered in any one locality occur in and around Puunene on Maui. From these trees, we secured 250 bags of pods during the last fruiting season.

Strange to say, the Ear-pod had not been tested out as a possible forest tree on our watersheds until very recently. Evidence supplied by some of our experimental plantings clearly indicates that this tree can be used to advantage in the lower zones of our watershed forests. Its rapid growth and the form and stature which it attains render it an ideal component of a mixed forest such as we desire to build. Its big seeds germinate readily, producing at once, large, strong-growing seedlings. This renders it an especially good subject for spot-planting in the open field, as the seedlings quickly over-top the Hilo grass and so require very little subsequent attention. The seedlings are easily handled in the nursery, for they are very resistant to the damping-off fungus and other ills which are prone to take heavy toll among the young seedlings in a nursery. The young trees stand handling and transplanting admirably well. Add to these merits the fact that the trees do remarkably well under the adverse soil conditions existing on our watersheds, and it will be quite evident that the Ear-pod should be given much consideration when formulating planting plans for our new forests.

There seems to be very little information in the literature regarding economic products which may be derived from *Enterolobium cyclocarpum*. A small amount of the timber is evidently being imported into the United States, where it is used as a cabinet wood and for interior decoration. No doubt, its use will become

more general in future years as the supply of the better-known tropical woods is depleted. The quality of the wood apparently varies considerably and is probably much influenced by the conditions under which the tree grew which produced the particular sample examined. The local-grown wood, which has come into our hands, is very soft and easily worked. It has a pretty grain and takes a nice polish. A specimen of "Jenisero," secured from a lumber dealer in San Francisco, is much harder than the Hawaiian-grown wood. The useful purposes which this tree and its products serve in other parts of the world may be learned from the authorities quoted below:

Enterolobium cyclocarpum (Jacq.) Griseb. Fl. Brit. W. Ind. 226. 1860.

Sinaloa to Tamaulipas, Vera Cruz, and Chiapas. Central America, West Indies, and northern South America.

Large unarmed tree, 12 to 30 meters high or larger, with broad spreading crown, the trunk 0.6 to 2.5 meters in diameter; bark rough; leaves bipinnate, the leaflets very numerous, linear-oblong, 10 to 12 mm. long, acute or obtuse; flowers small, white, sessile in dense heads; fruit flat, coiled, 8 to 11 cm. in diameter, dark brown, lustrous; seeds dark brown or black, about 12 mm. long; wood hard, resistant, elastic, grayish tinged with yellow, sometimes livid and mottled.

The tree grows rapidly and makes an excellent shade tree because of the broad top. The large trunks are used for canoes, water troughs, etc., and the wood is very durable in water. It is employed in carpentry and cabinet work. The pods are said to be an excellent feed for cattle, and the seeds as well as the young pods are sometimes cooked to be used for human food. The fruit and bark are rich in tannin. Rose reports that in Sinaloa the bark and fruit are used as a substitute for soap in washing woolen goods and that a syrup made from the bark is used for colds. The fruit is used as a soap substitute in Venezuela also. The gum which exudes from the trunk is employed in Sinaloa as a remedy for bronchitis.—Standley, Paul C., page 391.

Timber known as "guanacaste," "conacaste," "pichwood," "Genizero," and South American walnut has been introduced into the markets of the United States, principally from Mexico and Central America, and is being used to considerable extent in California cities for interior trim in houses and office buildings. The species producing this is *Enterolobium cyclocarpum* Gris., a tree sometimes 125 feet or more in height, with a broad, spreading crown, a thick trunk sometimes 10 feet in diameter, and leaves and fruits similar to the "timbo" of Argentina.

The timber enters the United States markets as roughly hewn logs averaging about 24 inches in diameter and from 10 to 14 feet in length, usually free of defects. There is considerable variation in density of the material, ranging from the consistency of white pine (*Pinus Strobus*) to that of walnut (*Juglans nigra*). The heavier material resembles walnut in general appearance and makes a fairly satisfactory substitute. . . .

Color walnut-brown or with various shadings; sometimes with a reddish tinge in part; luster rather high. Sapwood dull white, merging gradually into the heartwood.

Odor and taste absent or not distinctive.

Very light, soft and spongy to moderately hard and firm. Sp. gr. (air-dry) 0.35 to 0.60. Weight 22 to 37 lbs. per cu. ft. Grain straight to somewhat rocy. Texture medium to coarse. Wood very easy to work, harder kinds take good polish, readily seasoned without warping and checking, fairly durable.—Record, Samuel J. and Mell, Clayton D., pp. 205, 206.

Jenisero. "*Enterolobium cyclocarpum.*" A brown, coarse grained cabinet wood from the West Coast of Central America. It is strong and tough and takes a beautiful and lasting polish. Jenisero is generally figured very beautifully and is used to a great extent in the interior finish of office buildings on the Pacific Coast. It is very little used in the Eastern States, but as it is a very plentiful wood, there is no doubt that it will in time become popular there. The Fairmont and Whitcomb Hotels and the Monadnock Building in San Francisco, are finished in Jenisero.—White, C. H., p. 7.

Literature Cited

Standley, Paul C. Contributions from the United States National Herbarium. 23:391.

Record, Samuel J., and Mell, Clayton D. Timbers of Tropical America. 1924.

White, C. H. Orgin and history of hardwoods of the world as used on the Pacific Coast.

Potash Fertilization on Ewa Plantation

By W. P. Alexander *

Potash fertilization of the cane has been placed upon a sound basis of control at the Ewa Plantation Company. Investigation was started six years ago and conclusions for individual fields based upon:

(1) Field plot experiments,

(2) Analysis of the soil for potash, and,

(3) Analysis of the crusher juice for potash have provided a practical and working foundation from which it can be decided whether or not the cane requires potash fertilization. The results have governed the application of potash over the plantation so that at the present time there are approximately:

(a) 800 acres or 10 per cent of total area where there is very good evidence that potash is needed in large doses and where returns have been secured from tests ranging from one-third of a ton to two tons of sugar per acre.

(b) 1100 acres or 14 per cent where there is only fair evidence that moderate amounts of potash will benefit the cane, and where returns of less than half a ton of sugar have been obtained.

(c) 1700 acres or 22 per cent where potash is applied in small amounts for insurance purposes. The data, here, are not conclusive one way or the other.

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(d) 2500 acres or 32 per cent where no potash is applied, but which is on the border line and must be observed very carefully for signs of potash deficiency.

(e) 900 acres or 11 per cent where potash is not needed, the evidence being good.

(f) 900 acres or 11 per cent where potash is not needed, the evidence being very good.

From the above data one can easily calculate the large financial gain which is the outcome of:

(1) Increased profits due to gains from extra potash fertilization.

(2) Decreased cost of fertilizer, the consequence of not applying potash to 4500 acres which previously received a certain amount in mixed fertilizers.

The inquiry has been thorough and careful, and has made possible a refinement in fertilizer control as regards potash. The expense of the investigation has been small, and because the results were of practical value, the better knowledge of fertilization needs of the cane under varied soil conditions have given profits that could not be expected under the "rule of thumb" regime.

No attempt will be made here to present the voluminous records obtained from:

1536 juice analyses from all fields (excluding Crop 1926),

1006 soil analyses; 753 by Ewa laboratory and 253 by the H. S. P. A. Experiment Station,

45 field experiments harvested from 1922 to 1926 covering 342 acres, having watercourse size plots, ⅓ to ½ acre each.

It is of some scientific interest to see just what data have been obtained upon which to base deductions and therefore certain typical examples of the data will be examined. It must be clearly understood that one has had to deal with the usual amount of experimental error in this investigation and certain contrary results have been secured. Taken as a whole, the findings are consistent and the evidence offered in this review will be given without trying to discuss discordant results. It is the general trend of the project and not specific details which will be presented.

Gains from Potash

Positive response of the cane to potash fertilizer has mainly been confined to fields of a particular alluvial soil type. It is a black adobe heavy clay. Usually poorer drainage and some salt accumulation accompanies this kind of soil.

Grouped below (Table 1) is a study of some of the tests harvested from fields of the so-called "wet" type.

TABLE 1

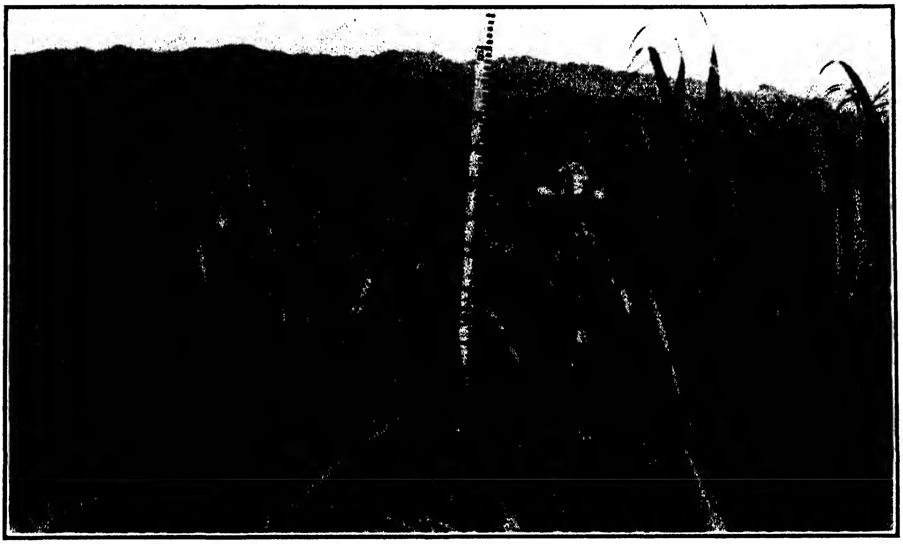
Cane Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Average Yields per Acre (Tons Cane) Potash Plots	Check Plots	Diff.	Per Cent Diff.
3-A	K-24	1924	30	800	Mol. Ash	87.36	84.41	+ 2.95	+ 3.49
3-A	K-24	1926	30	Residual	Effect	104.73	102.07	+ 2.66	+ 2.61
Average 2 crops						96.05	93.24	+ 2.81	+ 3.01
3-A	K-37	1926	23	250	Pot. Nit.....	89.79	87.16	+ 2.63	+ 3.02
3-A	K-38	1926	11	250	Sul. Pot......	92.10	88.34	+ 3.76	+ 4.26
3-A	K-39	1926	7	500	Sul. Pot......	102.97	89.10	+13.87	+15.57
3-A	K-39	1926	10	250	Sul. Pot......	100.13	89.10	+11.03	+12.38
3-A	K-39	1926	10	100	Sul. Pot......	94.34	89.10	+ 5.24	+ 5.88
3-C	K-16	1923	6	100	Sul. Pot......	84.89	82.86	+ 2.03	+ 2.45
3-C	K-16	1925	6	200	Sul. Pot......	119.08	116.85	+ 2.23	+ 1.91
3-C	K-16	1926	6	200	Sul. Pot......	84.57	80.09	+ 4.48	+ 5.59
Average 3 crops						96.18	93.27	+ 2.91	+ 3.12
3-C	K-33	1925	11	350	Mol. Ash	107.74	105.79	+ 1.95	+ 1.84
3-D	K-40	1926	20	100	Sul. Pot......	70.22	63.26	+ 6.96	+11.00
11	K-8	1923	8	100	Sul. Pot......	86.38	80.51	+ 5.87	+ 7.29
11	K-34	1925	21	400,800	Mol. Ash	103.00	98.68	+ 4.32	+ 4.38
14-B	K-27	1925	2	250	Sul. Pot......	122.68	112.50	+10.18	+ 9.05
20-C	K-32	1925	21	400	Mol. Ash	111.38	110.80	+ 0.58	+ 0.52
Average all experiments						97.59	92.54	+ 5.05	+ 5.46

Potash Applied
Plot 15-K, Field 3-A, showing residual effect from molasses ash. Previous crop 10.65 tons sugar per acre.

No Potash
Plot 14-X, Field 3-A, showing less growth where potash has been withheld. Previous crop 9.55 tons sugar per acre.

It is seen that the small but consistent increases in cane yields are produced with 100 to 800 pounds of potash applied in the form of sulphate, nitrate and molasses ash. The economical amount to apply, the proper time to apply and the best form are questions still unsettled. The gains in cane yield ranged from 2 to 14 tons per acre and averaged 5 tons per acre.



No Potash
Plot 16-X, Field 3-A, showing less growth where no potash was applied.

Potash Applied
Plot 15-K, Field 3-A, showing residual effect from molasses ash.

TABLE 2

Quality Ratio

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Quality Ratio Potash Plots	Check Plots	Diff.	Per Cent Diff.
3-A	K-24	1924	30	800	Mol. Ash	8.01	8.20	+ 0.19	+ 2.32
3-A	K-24	1926	30	Residual	Effect	8.42	8.88	+ 0.46	+ 5.18
Average 2 crops						8.22	8.54	+ 0.32	+ 3.75
3-A	K-37	1926	23	250	Pot. Nit.....	8.52	8.78	+ 0.26	+ 2.96
3-A	K-38	1926	10	250	Sul. Pot......	8.15	8.51	+ 0.36	+ 4.23
3-A	K-39	1926	7	500	Sul. Pot......	8.22	8.54	+ 0.32	+ 3.75
3-A	K-39	1926	10	250	Sul. Pot......	8.36	8.54	+ 0.18	+ 2.11
3-A	K-39	1926	10	100	Sul. Pot......	8.63	8.54	— 0.09	— 1.05
3-C	K-16	1923	6	100	Sul. Pot......	9.02	9.15	+ 0.13	+ 1.42
3-C	K-16	1925	6	200	Sul. Pot......	10.11	10.71	+ 0.60	+ 5.60
3-C	K-16	1926	6	200	Sul. Pot......	8.22	8.43	+ 0.21	+ 2.49
Average 3 crops						9.12	9.43	+ 0.31	+ 3.29
3-C	K-33	1925	11	350	Mol. Ash	9.90	10.44	+ 0.54	+ 5.17
3-D	K-40	1926	20	100	Sul. Pot......	8.34	8.53	+ 0.19	+ 2.23
11	K-8	1923	8	100	Sul. Pot......	9.26	9.43	+ 0.17	+ 1.80
11	K-34	1925	21	400,800	Mol. Ash	7.79	7.80	+ 0.01	+ 0.13
14-B	K-27	1925	2	250	Sul. Pot......	8.29	8.56	+ 0.27	+ 3.15
20-C	K-32	1925	21	400	Mol. Ash	7.42	7.70	+ 0.28	+ 3.64
Average all experiments						8.54	8.80	+ 0.26	+ 2.95

Evidence presented here (Table 2) shows that the sucrose content of the cane may be improved by potash fertilization. At first, in 1922-23 the preliminary findings showing that the quality ratio was better in the potash plots was questioned, as such results were contrary to the published data* on the subject. However, further results corroborated the original conclusions as may be seen above.

Graph 1, a plot-to-plot comparison of Experiment K-24, is an example of how very regular such a low quality ratio may be with an experiment. All tests were not as consistent as this, but the general trend is for cane grown on this type of soil to not only have more cane, but almost a proportionate increase in the sucrose content. Such a benefit from potash fertilization was unexpected and has been very gratifying, inasmuch as every effort is being made at Ewa Plantation to better the quality of the cane.

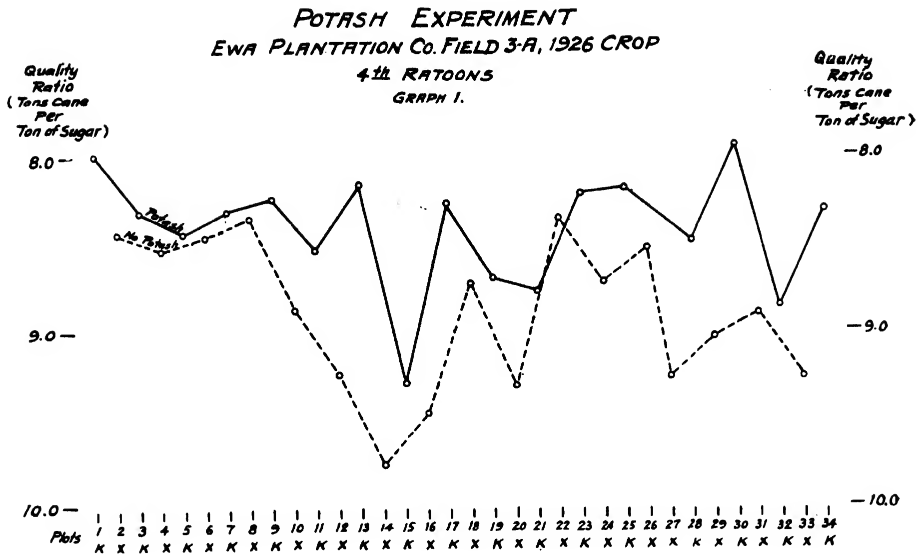
TABLE 3

Sugar Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Yields per Acre (Tons Sugar) Potash Plots	Check Plots	Diff.	Per Cent. Diff.
3-A	K-24	1924	30	800	Mol. Ash	10.91	10.29	+ 0.62	+ 6.03
3-A	K-24	1926	30	Residual	Effect	12.44	11.49	+ 0.95	+ 8.27
Average 2 crops						11.68	10.89	+ 0.79	+ 7.25
3-A	K-37	1926	23	250	Pot. Nit.....	10.54	9.93	+ 0.61	+ 6.14
3-A	K-38	1926	10	250	Sul. Pot......	11.30	10.38	+ 0.92	+ 8.86
3-A	K-39	1926	7	500	Sul. Pot......	12.52	10.43	+ 2.09	+20.04
3-A	K-39	1926	10	250	Sul. Pot......	11.98	10.43	+ 1.55	+14.86
3-A	K-39	1926	10	100	Sul. Pot......	10.93	10.43	+ 0.50	+ 4.79
3-C	K-16	1923	6	100	Sul. Pot......	9.42	9.06	+ 0.36	+ 3.97
3-C	K-16	1925	6	200	Sul. Pot......	11.78	10.91	+ 0.87	+ 7.97
3-C	K-16	1926	6	200	Sul. Pot......	10.29	9.50	+ 0.79	+ 8.32
Average 3 crops						10.50	9.82	+ 0.68	+ 6.92
3-C	K-33	1925	11	350	Mol. Ash	10.88	10.13	+ 0.75	+ 7.40
3-D	K-40	1926	20	100	Sul. Pot......	8.42	7.42	+ 1.00	+13.48
11	K-8	1923	8	100	Sul. Pot......	9.33	8.54	+ 0.79	+ 9.25
11	K-34	1925	21	400,800	Mol. Ash	13.22	12.65	+ 0.57	+ 4.51
14-B	K-27	1925	2	250	Sul. Pot......	14.80	13.14	+ 1.66	+12.63
20-C	K-32	1925	21	400	Mol. Ash	15.01	14.39	+ 0.62	+ 4.31
Average all experiments						11.49	10.57	+ 0.92	+ 8.70

The increased yield of sugar per acre (see Table 3) in the potash plots averaged almost one ton of sugar. The different tests showed various increases but with few exceptions all experiments installed in this soil type have showed that potash could be applied with a profit. At present prices, 100 pounds of K_2O costs not over eight dollars per acre applied.

* *The Hawaiian Planters' Record*, Vol. XXVII, p. 117; Vol. XXX, p. 60.



Graph 1.

TABLE 4

Soil Analysis—Per Cent Potash in Soil

(Analyses by Ewa Laboratory and H. S. P. A. Experiment Station)
1922-1926

Field	HCl Sol.	Citrate Sol.
3-A	0.18	0.018
3-C	0.20	0.018
3-D	0.26	0.013
11	0.17	0.015
14-B	0.18	0.012
20-C	0.30	0.014
Average	0.22	0.015

Analyses of the soil from the experiments under consideration (Table 4) were made by the Ewa laboratory and the Experiment Station of the H. S. P. A. They show a deficiency of potash in the soil from these experiments with an average of 0.22 per cent K_2O as shown by hydrochloric acid digestion and 0.015 per cent K_2O by the citrate acid method. The results from the former method seem to be less consistent than from the latter where a difference of only 0.005 is found between the high and low analyses.

Juice Analysis

To supplement the data obtained from field experiments and soil analyses the per cent of potash in the crusher juice is secured. The Sherrill method* was used and when results are interpreted it must be remembered that the figures obtained

* *The Hawaiian Planters' Record,* Volume XXVII, p. 112, April, 1923.

are not very exact, but are only indicative. The reason for using such a questionable method is that it is simple and can very easily be adopted by the routine of the ordinary plantation sugar laboratory. It is better than no information at all. The following results (Table 5) were obtained from some of the experiments where potash was needed:

TABLE 5

Per Cent Potash in Crusher Juice

Field	Exp. No.	Crop	No. of Samples Composited	Lbs. K_2O	Forms	K_2O in Crusher Juice: Potash Plots	Check Plots	Diff.
3-A	K-24	1924	Composited	800	Mol. Ash.......	0.73	0.36	+0.37
3-A	K-37	1926	28	250	Pot. Nit........	0.19	0.11	+0.08
3-A	K-38	1926	39	250	Sul. Pot........	0.36	0.30	+0.06
3-C	K-16	1923	14	100	Sul. Pot........	0.75	0.55	+0.20
3-C	K-16	1925	12	200	Sul. Pot........	0.45	0.35	+0.10
3-C	K-16	1926	14	200	Sul. Pot........	0.22	0.47	—0.25
Average 3 crops						0.47	0.46	+0.01
3-C	K-33	1925	14	350	Mol. Ash.......	0.44	0.45	—0.01
3-D	K-40	1926	45	500, 250, 200	Sul. Pot........	0.48	0.35	+0.13
11	K-34	1925	32	400, 800	Mol. Ash.......	0.93	0.74	+0.19
14-B	K-27	1925	3	250	Sul. Pot........	0.83	0.58	+0.25
20-C	K-32	1925	22	400	Mol. Ash.......	0.32	0.34	—0.02
Average all tests						0.52	0.42	+0.10

Tests Showing no Response or Loss for Potash Fertilization

It has been shown that there are soil conditions where potash fertilizer will be very profitable. The opposite also seems to be true on certain other types of soil found at Ewa Plantation. An examination of the fields where these tests are located shows that the lime content is very high. They belong to the so-called coral or semi-coral type, i.e., the soil has been washed down from the mountains upon the disintegrated coral.

There are given below (Table 6) the yields, soil and juice analyses from a group of tests where potash failed to improve cane yields or the quality of the juice. It will be noted that potash fertilization tends to depress cane yields.

TABLE 6

Cane Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Yields per Acre (Tons Cane): Potash Plots	Check Plots	Diff.	Per Cent Diff.
19-F	K-7	1923	11	100	Sul. Pot......	136.03	146.84	—10.81	— 7.36
19-F	K-7	1925	8	100	Sul. Pot......	141.26	141.99	— 0.73	— 0.51
19-F	K-7	1926	7	100	Sul. Pot......	90.33	95.21	— 4.88	— 5.13
Average 3 crops						122.54	128.01	— 5.47	— 4.27
22-A	K-23	1924	8	100	Sul. Pot......	85.14	86.71	— 1.57	— 1.81
22-A	K-23	1925	4	100	Sul. Pot......	81.96	84.23	— 2.27	— 2.70
Average 2 crops						83.55	85.47	— 1.92	— 2.25
22-B	K-18	1923	10	200	Sul. Pot......	47.71	52.00	— 4.29	— 8.25
Average all experiments						97.07	101.16	— 4.09	— 4.04

The quality ratios from the potash and check plots as given herewith do *not* show that potash has influence on the sucrose content one way or the other if cane yields are the same or poorer.

TABLE 7

Quality Ratio

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Quality Ratio Potash Plots	Check Plots	Diff.	Per Cent Diff.
19-F	K-7	1923	11	100	Sul. Pot......	9.89	9.78	— 0.11	— 1.12
19-F	K-7	1925	8	100	Sul. Pot......	9.19	9.27	+ 0.08	+ 0.86
19-F	K-7	1926	7	100	Sul. Pot......	9.74	9.74	....	....
Average 3 crops						9.61	9.60	— 0.01	— 0.10
22-A	K-23	1924	8	100	Sul. Pot......	9.51	9.62	+ 0.11	+ 1.14
22-A	K-23	1925	4	100	Sul. Pot......	8.11	8.00	— 0.11	— 1.38
Average 2 crops						8.81	8.81	....	....
22-B	K-18	1923	10	200	Sul. Pot......	10.20	10.34	+ 0.14	+ 1.35
Average all experiments						9.44	9.46	+ 0.02	+ 0.21

Applications of potash can be dispensed with under these conditions (Table 7).

TABLE 8

Sugar Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Yields per Acre (Tons Sugar) Potash Plots	Check Plots	Diff.	Per Cent Diff.
19-F	K-7	1923	11	100	Sul. Pot......	13.75	15.01	— 1.26	— 8.39
19-F	K-7	1925	8	100	Sul. Pot......	15.37	15.32	+ 0.05	+ 0.33
19-F	K-7	1926	7	100	Sul. Pot......	9.27	9.78	— 0.51	— 5.21
Average 3 crops						12.80	13.37	— 0.57	— 4.26
22-A	K-23	1924	8	100	Sul. Pot......	8.95	9.01	— 0.06	— 0.67
22-A	K-23	1925	4	100	Sul. Pot......	10.11	10.53	— 0.42	— 3.99
Average 2 crops						9.53	9.77	— 0.24	— 2.46
22-B	K-18	1923	10	200	Sul. Pot......	4.68	5.03	— 0.35	— 6.96
Average all experiments						10.36	10.78	— 0.42	— 3.90

Soil analyses made from the above tests are high in potash, as shown from these data (Table 9).

TABLE 9

Soil Analysis—Per Cent Potash in Soil

Field	HCl Sol.	Citrate Sol.
19-F	1.19	0.078
22-A	0.29	0.024
22-B	0.39	0.040
Average	0.62	0.047

TABLE 10

Juice Analysis—Per Cent Potash in Crusher Juice

						K_2O in Crusher Juice		
Field	Exp. No.	Crop	No. of Samples	Lbs. K_2O	Forms	Potash Plots	Check Plots	Diff.
19-F	K-7	1923	13	100	Sul. Pot........	1.16	1.21	—0.05
19-F	K-7	1925	13	100	Sul. Pot........	1.52	1.52	......
Average 2 crops						1.34	1.37	—0.03
22-A	K-23	1925	21	100	Sul. Pot........	1.40	1.50	—0.10
Average all tests						1.36	1.41	—0.05

The crusher juice (Table 10) reflects the high content of potash, as shown by soil samples. The average is 1.4 per cent K_2O.

Fields Which May or May Not Respond to Potash

The bulk of the fields lie between the above two extremes, namely, the adobe type needing potash and the coral type where potash is not wanted. Just how long potash fertilizer can be held off on these fields without depletion of the natural reserve remains to be seen. There is a chance that before long potash fertilizer will be needed again. The amount removed during each crop is very large. Probably between 200 and 300 pounds of K_2O is taken up from the soil in the heaviest cane crops. This cannot go on forever and to guard against injury to the fertility of the soil, experimental plots with and without potash are continued indefinitely.

Examples of tests where negative results have been secured, but where potash is sometimes applied to surrounding fields for insurance purposes, is given below (Table 11):

TABLE 11

Cane Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Yields per Acre (Tons Cane) Potash Plots	Check Plots	Diff.	Per Cent Diff.
A	K-2	1922	13	100	Sul. Pot......	59.79	59.21	+ 0.58	+ 0.98
A	K-2	1924	13	100	Sul. Pot......	107.56	108.53	— 0.97	— 0.89
A	K-2	1926	13	100	Sul. Pot......	110.09	107.52	+ 2.57	+ 2.39
Average 3 crops						92.48	91.75	+ 0.73	+ 0.80
1-A	K-29	1925	21	200	Sul. Pot......	134.27	133.60	+ 0.67	+ 0.50
1-E	K-36	1926	44	250	Sul. Pot......	113.22	111.66	+ 1.56	+ 1.40
2-A	K-31	1925	5	100	Sul. Pot......	137.81	137.09	+ 0.72	+ 0.53
7	K-1	1922	9	100	Sul. Pot......	92.80	94.99	— 2.19	— 2.31
7	K-1	1924	9	100	Sul. Pot......	109.41	108.70	+ 0.71	+ 0.65
7	K-1	1925	12	100	Sul. Pot......	91.01	90.69	+ 0.32	+ 0.35
Average 3 crops						97.74	98.13	— 0.39	— 0.40
19-B	K-30	1925	7	100	Sul. Pot......	130.21	129.11	+ 1.10	+ 0.85
19-D	K-14	1923	23	50	Sul. Pot......	82.41	83.85	— 1.44	— 1.72
19-D	K-14	1924	24	100	Sul. Pot......	76.37	75.85	+ 0.52	+ 0.69
19-D	K-14	1926	25	100	Sul. Pot......	74.73	76.70	— 1.97	— 2.57
Average 3 crops						77.84	78.80	— 0.96	— 1.22
25-A	K-21	1924	12	100	Sul. Pot............	113..99	114..14	— 0..15	— 0..13
25-A	K-21	1926	8	100	Sul. Pot......	92.45	93.07	— 0.62	— 0.67
Average 2 crops						103.22	103.61	— 0.39	— 0.38
Average all experiments						101.74	101.65	+ 0.09	+ 0.09

A study of the above compilation (Table 11) shows that there is no pronounced gain or loss in cane yields due to potash fertilization on these eight representative fields scattered from one end of the plantation to the other, excluding the adobe and coral fields. Average cane yields are within experimental error.

TABLE 12

Quality Ratio

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Quality Ratio Potash Plots	Check Plots	Diff.	Per Cent Diff.
A	K-2	1922	13	100	Sul. Pot......	8.55	8.55	....	....
A	K-2	1924	13	100	Sul. Pot......	8.32	8.48	+ 0.16	+ 1.89
A	K-2	1926	13	100	Sul. Pot......	8.76	8.72	— 0.04	— 0.46
Average 3 crops						8.54	8.58	+ 0.04	+ 0.47
1-A	K-29	1925	21	200	Sul. Pot......	8.12	8.21	+ 0.09	+ 1.10
1-E	K-36	1926	44	250	Sul. Pot......	8.04	8.10	+ 0.06	+ 0.74
2-A	K-31	1925	5	100	Sul. Pot......	8.21	8.29	+ 0.08	+ 0.97
7	K-1	1922	9	100	Sul. Pot......	8.08	8.17	+ 0.09	+ 1.10
7	K-1	1924	9	100	Sul. Pot......	10.02	10.13	+ 0.11	+ 1.09
7	K-1	1925	12	100	Sul. Pot......	8.09	8.08	— 0.01	— 0.12
Average 3 crops						8.73	8.79	+ 0.06	+ 0.68
19-B	K-30	1925	7	100	Sul. Pot......	7.85	7.90	+ 0.05	+ 0.63
19-D	K-14	1923	23	50	Sul. Pot......	10.29	10.22	— 0.07	— 0.68
19-D	K-14	1924	24	100	Sul. Pot......	7.94	7.97	+ 0.03	+ 0.38
19-D	K-14	1926	25	100	Sul. Pot......	8.07	8.08	+ 0.01	+ 0.12
Average 3 crops						8.77	8.76	— 0.01	— 0.11
25-A	K-21	1924	12	100	Sul. Pot......	7.62	7.58	— 0.04	— 0.53
25-A	K-21	1926	8	100	Sul. Pot......	8.89	9.00	+ 0.11	+ 1.22
Average 2 crops						8.26	8.29	+ 0.03	+ 0.36
Average all experiments						8.46	8.50	+ 0.04	+ 0.47

Potash failed to improve sucrose content where no gains in cane yields were secured (Table 12). The quality ratios of the potash-treated and untreated plots are remarkably close.

TABLE 13

Sugar Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Yields per Acre (Tons Sugar) Potash Plots	Check Plots	Diff.	Per Cent Diff.
A	K-2	1922	13	100	Sul. Pot......	6.99	6.93	+ 0.06	+ 0.87
A	K-2	1924	13	100	Sul. Pot......	12.79	12.73	+ 0.06	+ 0.47
A	K-2	1926	13	100	Sul. Pot......	12.57	12.33	+ 0.24	+ 1.95
Average 3 crops						10.78	10.66	+ 0.12	+ 1.13
1-A	K-29	1925	21	200	Sul. Pot......	16.54	16.27	+ 0.27	+ 1.65
1-E	K-36	1926	44	250	Sul. Pot......	14.08	13.78	+ 0.30	+ 2.18
2-A	K-31	1925	5	100	Sul. Pot......	16.79	16.54	+ 0.25	+ 1.51
7	K-1	1922	9	100	Sul. Pot......	11.49	11.63	— 0.14	— 1.20
7	K-1	1924	9	100	Sul. Pot......	10.92	10.73	+ 0.19	+ 1.77
7	K-1	1925	12	100	Sul. Pot......	11.25	11.22	+ 0.03	+ 0.27
Average 3 crops						11.22	11.19	+ 0.03	+ 0.27
19-B	K-30	1925	7	100	Sul. Pot......	16.59	16.34	+ 0.25	+ 1.53
19-D	K-14	1923	23	50	Sul. Pot......	8.01	8.20	— 0.19	— 2.32
19-D	K-14	1924	24	100	Sul. Pot......	9.62	9.52	+ 0.10	+ 1.05
19-D	K-14	1926	25	100	Sul. Pot......	9.26	9.49	— 0.23	— 2.42
Average 3 crops						8.96	9.07	— 0.11	— 1.21
25-A	K-21	1924	12	100	Sul. Pot......	14.96	15.06	— 0.10	— 0.66
25-A	K-21	1926	8	100	Sul. Pot......	10.40	10.34	+ 0.06	+ 0.58
Average 2 crops						12.68	12.70	— 0.02	— 0.16
Average all experiments						12.15	12.07	+ 0.08	+ 0.66

Negative results are shown for the majority of these tests (Table 13), although some of the areas such as A Field and Fields Nos. 1-E, 2-A and 19-B are examples of fields that are on the border line, and potash is being applied to the surrounding cane in order that no chances may be taken that the cane will suffer from potash starvation. Soil from these fields gave the following analyses for potash:

TABLE 14

Soil Analysis—Per Cent Potash in Soil

Field	HCl Sol.	Citrate Sol.
A	0.34	0.031
1-A	0.33	0.020
1-E	0.33	0.027
2-A	0.27	0.014
7	0.27	0.019
19-B	0.30	0.022
19-D	0.22	0.031
25-A	0.20	0.043
Average	0.28	0.026

Juice Analysis

The juice from the same fields showed the results shown in Table 15, giving an average of 0.9 per cent K_2O in the crusher juice.

TABLE 15

Per Cent Potash in Crusher Juice

Field	Exp. No.	Crop	No. of Samples	Lbs. K_2O	Forms	K_2O in Crusher Juice Potash Plots	Check Plots	Diff.
A	K-2	1926	35	100	Sul. Pot........	0.78	0.65	+0.13
1-A	K-29	1925	55	200	Sul. Pot........	0.58	0.64	—0.06
1-E	K-36	1926	48	250	Sul. Pot........	1.19	1.26	—0.07
2-A	K-31	1925	11	100	Sul. Pot........	0.96	0.93	+0.03
7	K-1	1924	Composited	100	Sul. Pot........	0.49	0.49	......
7	K-1	1925	45	100	Sul. Pot........	0.57	0.46	+0.11
Average 2 crops						0.53	0.48	+0.05
19-B	K-30	1925	9	100	Sul. Pot........	0.83	0.73	+0.10
19-D	K-14	1924	34	100	Sul. Pot........	1.54	1.49	+0.05
25-A	K-21	1924	Composited	100	Sul. Pot........	0.51	0.73	—0.22
25-A	K-21	1926	27	100	Sul. Pot........	1.36	1.14	+0.22
Average 2 crops						0.94	0.94	......
Average all tests						0.88	0.85	+0.03

CORRELATION OF DIFFERENT FACTORS

The data reviewed in the preceding pages are summarized below:

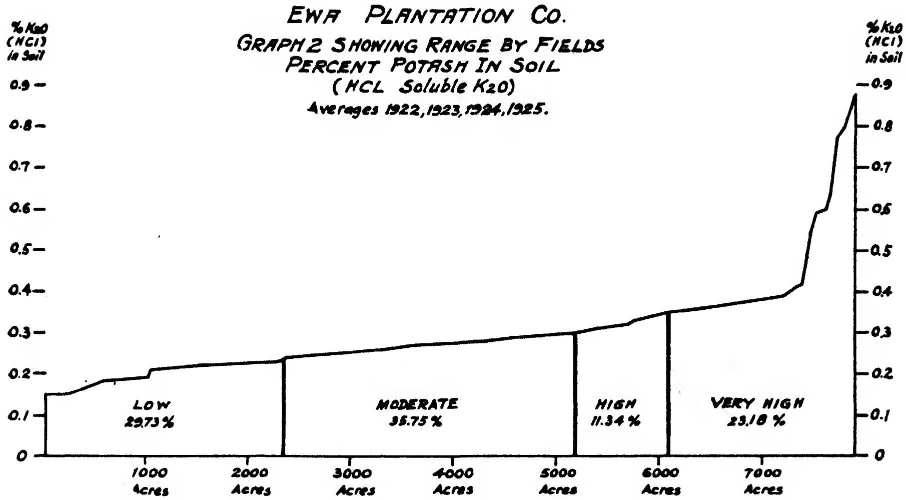
	Soil Type	Average Gain or Loss Cane	Q. R.	Sugar	K_2O in Soil HCl	Cit.	K_2O in Crusher Juice
Gain for Potash.....	Adobe Poor Drained......	+5.05	+0.26	+0.92	0.22%	0.015%	0.42%
No Gain for Potash.. Negative Results	Coral or Semi-coral.......	—4.09	+0.02	—0.42	0.62%	0.047%	1.41%
More Data Needed for Further Crops...	General Ewa and Red Soil.	+0.09	+0.04	+0.08	0.28%	0.026%	0.85%

After ironing out all the inconsistences by averages, the direct correlation as exhibited in the above figures between cane yields, soil analysis, and juice analysis, furnish one with a proof that in the main it is possible to rely on these factors for control of potash fertilization.

Results Applied to Field Practice

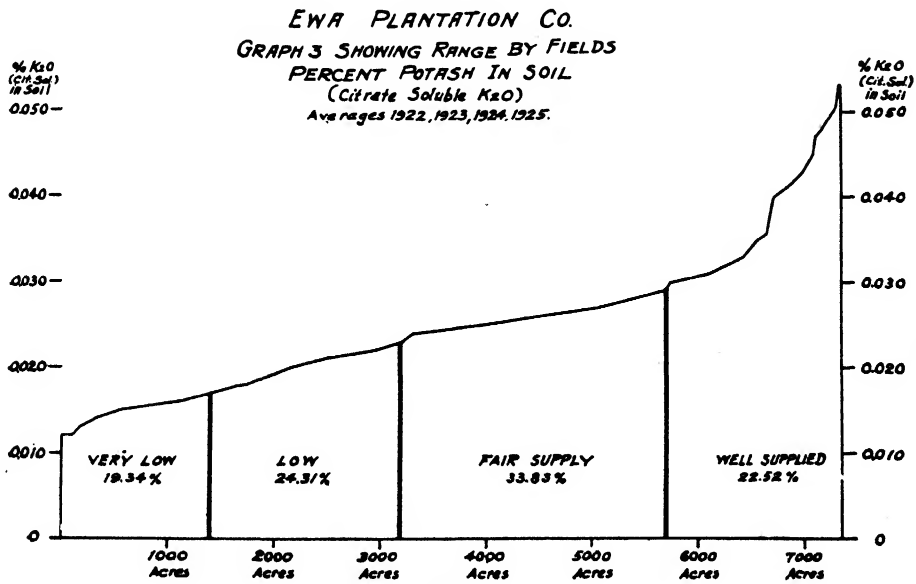
A soil survey of the plantation has been used in conjunction with the field experiments. Every off season the laboratory analyzes from 150 to 200 soil

samples. The Experiment Station of the H. S. P. A. cooperated in making the preliminary soil survey. The range of potash in the soil from different fields is shown on Graphs 2 and 3.



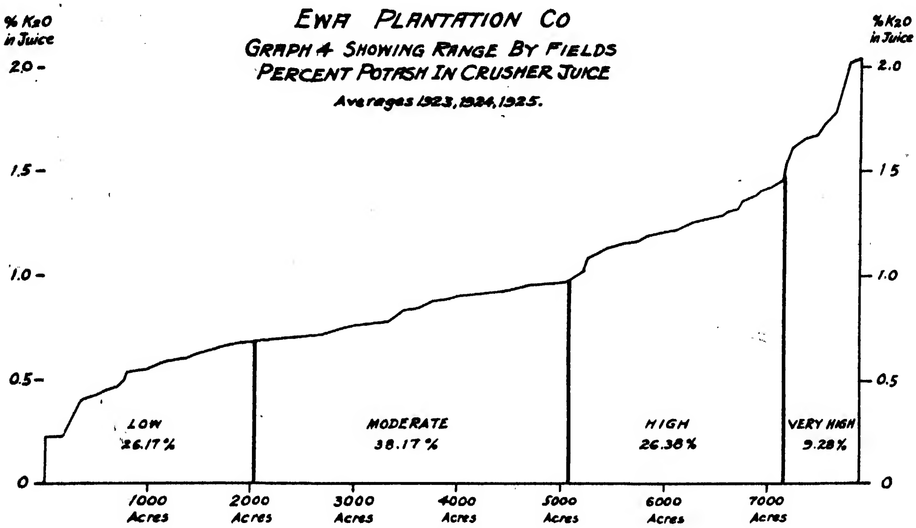
Graph 2.

During four crops the potash content of the crusher juice has been obtained. By procuring a continuous sample of the juice at the mill, it is believed that one is able to obtain a good approximation of the per cent of potash present in the cane grown from a particular field or section of a field. If the potash in the juice is high, the theory is that the soil contains a plentiful supply of potash and where there is little potash in the juice, there is a deficiency of potash in the soil. The information secured in this way has been fairly satisfactory if interpreted in



Graph 3.

light of field tests and correlated with soil analysis. By itself, it probably has little value. Practically every field has had the juice tested twice (1923-1925 or 1924-1926) and on the whole the relative standing of potash in the soil as represented by crusher juice samples has furnished information to be used to help decide potash fertilizer practice. The range of K_2O in the juice is given in Graph 4.



Graph 4.

Certain arbitrary standards have been used to classify the fields as to their potash content (Table 16). They are tentative and may be changed as more data are secured.

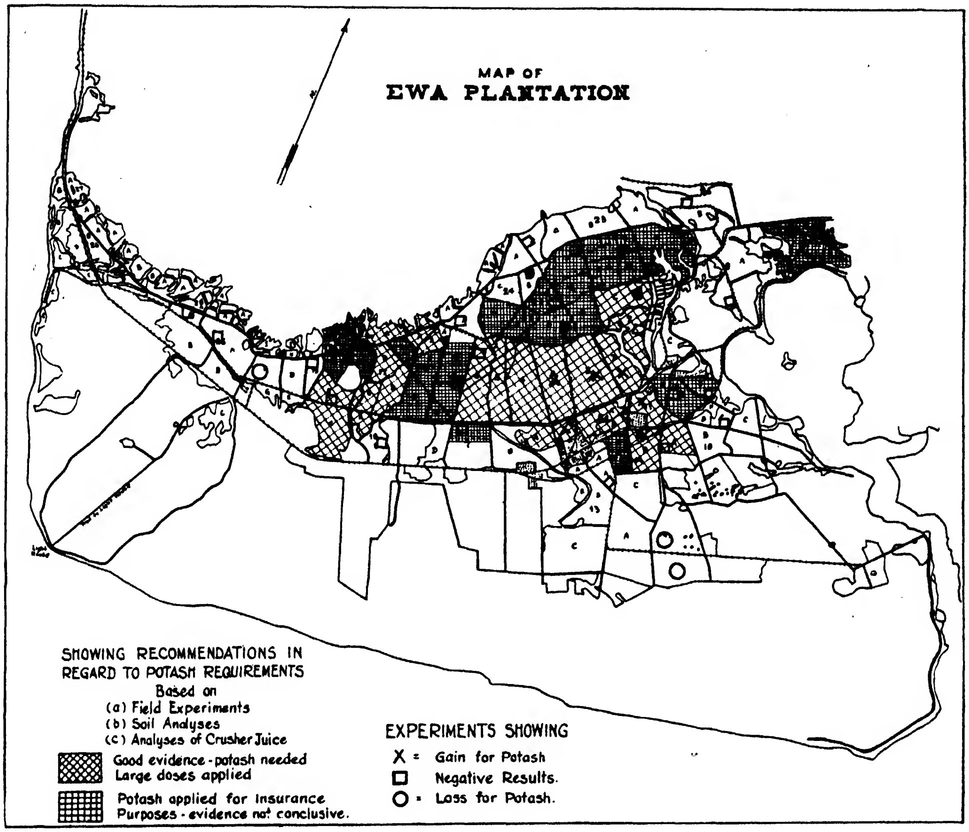
TABLE 16

	Potash in Soil HCl	Potash in Soil Citrate	Potash in Juice
Very Low	Below 0.20	Below 0.017	Below 0.50
Low	0.20–0.25	0.017–0.023	0.50–0.70
Moderate	0.25–0.30	0.023–0.030	0.70–1.00
High	0.30–0.35	0.030–0.040	1.00–1.50
Very High	Above 0.35	Above 0.040	Above 1.50

With this data in hand a map of the plantation has been compiled giving the recommendations as regards potash fertilizer requirements.

Summary

1. An endeavor has been made to show how it is possible for the practical plantation man to base recommendations for potash fertilization on a correlation of the three factors—field plot tests which are most important; soil analysis which must be interpreted liberally; and juice analysis which may be subject to considerable variation.



2. Potash fertilization has increased cane yields at Ewa. This increase in cane yield was often accompanied by an improvement in sucrose content, making a double benefit. At present prices extra applications of sulphate of potash, potash nitrate, and molasses ash proved profitable.

3. The area at Ewa where potash is certain to be needed by the cane is limited. On other sections small doses may be applied for insurance purposes or a saving may be effected by applying no potash at all.

4. Safety demands that potash be applied when soil shows less than 0.020 per cent citrate soluble K_2O. Response seems certain when 0.015 per cent K_2O is found in the soil.

5. Juice analysis of the cane ground at the mill furnishes a simple method of determining potash but is a poorer index of the relative amount of potash in the soil and should be used with caution. Juice analyzing with a 0.50 per cent K_2O or less indicated that the soil upon which the cane was grown was weak in potash. A danger mark seemed to be 0.70 per cent K_2O.

Remarks on the Genera of Spear-Bearing Nematodes Found in Hawaii, With a Table for Their Identification

By Gertrude Henderson

For economic reasons it is necessary to identify the nematodes found inhabiting and surrounding plants in the field and for this purpose these so-called "free living" nematodes may be subdivided into three classes:

1. Nematodes possessing a spear-like piercing armature situated in the pharyngeal cavity.
2. Nematodes possessing a pharyngeal tooth or teeth.
3. Nematodes entirely devoid of pharyngeal armature.

This classification is based upon the fundamental differences in anatomical structure and their relationships to the life habits and functional effects produced.

A variety of classifications already exists, but for agricultural purposes this method may be found simplest and most satisfactory as the spear-bearing group are of such enormous economic importance on account of their highly destructive action upon plants.

The difficulties of taxonomic investigation have been enormously increased by reason of the absence of a really satisfactory technique and because of the relative scarcity of literature dealing with this work.

From time to time individual works have been published dealing with this subject, but as yet no one has attempted to consider the entire genera as a whole and for this reason, in order to facilitate systematic classification, a generic reference table has been compiled including all spear-bearing nematodes so far as they are known to the writer.

This table is based upon the findings of Bastian, Cobb, Microletsky and others, and although by no means complete, it has proved of considerable value in our own taxonomic work and will be published in this issue.

From the table it may be seen that the numbers of spear-bearing genera assume considerable proportions and their economic significance may be more fully realized when the function and highly destructive effects of the spear-like armature is appreciated.

The spear is a sharply pointed tubular structure communicating directly with the oesophagus and is situated in the floor of the pharyngeal cavity.

The entire organ is protusile and is controlled by the rythmic action of a set of muscular structures to which it is attached and by means of which its powerful piercing action is effected.

The spear itself may present a variety of structural differences according to the species of nematode under consideration. It is a highly chitinized, hollow tube, and is believed solely instrumental in penetrating the hardened exterior of such objects (presumably plants) as the nematode desires to pierce either for purposes of nourishment or actual habitation.

The commonest example of this is found in the widespread destructive attack so frequently present in our commonest plants. The oval spear punctures the roots, effects an entrance and eventually the entire organism is installed within the root tissues themselves. The extreme seriousness of such an invasion and the subsequent depreciation of tissue vitality is apparent even to the most uninformed.

Apart from the seriousness of the mere mechanical invasion, there are the additional factors of toxin formation, bacterial infection and fungoid infestation to be considered. Each in itself is of grave importance and each may in turn jeopardize the life of the plant affected.

Given suitable conditions there is no reason why all four should not proceed symbiotically in perfect unison and rapidly produce destruction of the entire root system.

The actual nematode punctures in themselves produce a local weakening of the root vitality and afford easy access and suitable environment for the countless myriads of bacteria and fungi invariably associated with soils of every description.

An appreciation of these parasitic conditions may in part explain the frequency and persistence of such enormous root mortality. By reason of its persistence, this mortality has come to be regarded by many as an inevitable sequence of normal plant development. That such an idea is erroneous may be stated without trepidation. Given suitable environment, freedom from organismal infestation, sufficient nourishment, and comparatively sterile conditions, a normal, healthy sugar cane plant produces roots of good vitality and persistence.

The extensive primary root system, relieved from the necessity of continually producing fresh roots to replace diseased areas, develops normally and affords a proper equilibrium for the development and vitality of the aerial portion of the entire plant system.

Generic Reference Table of Spear-bearing Nematodes

1. 46 Spear with the base distinctly enlarged, consisting of either a single structure or of three structures more or less amalagamated together distally.
2. 9 Spear consisting of three pieces either separate or fused together at their distal ends, (rather indefinite).
3. 4 Spear apparently consisting of three separate spines; ''Kappchen'' present (spear cap); oesophagus muscular.......................................*Diphtherophora.*
4. 3 Spear consisting of three pieces fused together apically, and with trifurcate base.
5. 6 Oesophagus with a distinct median bulb and an enlarged posterior portion; base of spear with three distinct swellings...................................*Tylopharynx.*
6. 5 Oesophagus without median bulb, only gradually enlarged posteriorly; spear split at base.
7. 8 Spear with a ''Kappchen'' (spear cap).........................*Tylolaimorphus.*
8. 7 Spear without a ''Kappchen'' (spear cap).......................*Tylencholaimus.*
9. 2 Spear formed of one piece, base distinctly enlarged.
10. 11 Cuticle with very distinct rings or reticulations broken or complete; spear strong and generally long (1/6 to 1/9 of body length).......................*Hoplolaimus.*
11. 10 Cuticle without distinct rings or reticulations.
12. 13 Spear massive, distinctly divided into two parts, the anterior half being chitinous, the basal half transparent, the base not very distinctly enlarged........*Nemonchus.*

13. 12 Spear not so massive and not divided into two parts.
14. 17 Oesophagus without a median bulb and with only a slight, gradual enlargement posteriorly.
15. 16 Spear very long and slender; oesophagus cylindrical or subcylindrical....*Xiphinema.*
16. 15 Spear shorter and thicker; oesophagus distinctly narrowed in middle..*Tylencholaimus.*
17. 14 Oesophagus with median bulbous swelling.
18. 21 Spear with a "Kappchen" (spear cap).
19. 20 Spear long and slender (¼ length of oesophagus), basal bulb small; anterior oesophageal swelling long; pharynx simple........................*Paratylenchus.*
20. 19 Spear much shorter, basal bulb large; pharynx apparently chitinized on apical half .... *Tylenchorhynchus.*
21. 18 Spear without a "Kappchen" (spear cap).
22. 23 Spear short, thick, apparently attached to the side of the wall of pharynx, apex slightly enlarged, base swollen and oblique............................*Archionchus.*
23. 22 Spear free from the base, not enlarged at apex, base not oblique.
24. 39 Oesophagus with a distinct median bulb and a distinct posterior swelling.
25. 28 Anteriorly with four large, distinct bristles or setae; bursa trapezoid.
26. 27 Cuticle prominently and longitudinally striate.........................*Atylenchus.*
27. 26 Cuticle not prominently and longitudinally striate....................*Eutylenchus.*
28. 25 Anteriorly without setae or bristles.
29. 30 Excretory pore behind the middle of body; adult female greatly enlarged.*Tylenchulus.*
30. 29 Excretory pore before middle of body.
31. 32 Oesophagus behind bulb indistinct, appearing as if intestine joined bulb..*Aphelenchus.*
32. 31 Oesophagus behind bulb distinct.
33. 34 Amphids large, oval, deep, often protruded (especially when fixed with Flemming's solution) .... *Triplonchium.*
34. 33 Amphids small, more obscure, not protruded.
35. 36 Males without bursa; adult females greatly swollen and incapable of movement.... *Heterodera.*
36. 35 Males with bursa; adult females not greatly swollen, capable of movement.
37. 38 Bursa lobate; spear very long (1/3 to 1/5 length of oesophagus)......*Dolichodorus.*
38. 37 Bursa plain; spear smaller (1/5 to 1/31 length of oesophagus)..........*Tylenchus.*
39. 24 Oesophagus without a median bulb.
40. 41 Spear very small or vestigial...................*Aphelenchulus, Tylencholaimellus.*
41. 40 Spear well developed.
42. 43 Spear trifurcate at base, or basal half considerably larger than distal half, subcylindrical.. *Tylencholaimus.*
43. 42 Spear bulbous at base.
44. 45 Spear long and thin; amphid small or absent; "Kappchen" (spear cap) present .... *Paratylenchus.*
45. 44 Spear small, amphid large, oval, amphid chamber deep, amphid often protruding, apparently no "Kappchen" (spear cap)........................*Triplonchium.*
46. 1 Spear composed of a single hollow piece, slightly and gradually enlarged to base, base truncate, not swollen or enlarged or produced into prongs.
47. 48 Oesophagus with a distinct median bulb; excretory pore present...........*Isonchus.*
48. 47 Oesophagus without a distinct median bulb; excretory pore absent.
49. 50 Anterior portion of pharynx large, cup shape, supported with radiating chitinous ribs or other structures, sometimes beset with small teeth.................*Actinolaimus.*
50. 49 Pharynx anteriorly small, without such armature.
51. 52 Spear very long, slender and flexible...............................*Trichodorus.*
52. 51 Spear thick, not flexible, proportionally shorter......................*Dorylaimus.*
a b Spear long, needle-like...*Longidorus.*
b a Spear not so long and needle-like, more spine-like.
c d Spear gradually enlarging from middle to base.........................*Doryllium.*

d c Spear without such enlargement of the base.
e f Oesophagus considerably swollen at the anterior end................*Dorylaimellus.*
f e Oesophagus not swollen at the anterior end.
g h Lip region discoid, expanded, sucker-like............................*Discolaimus.*
h g Lip region not expanded.
j k Oesophagus cylindrical or slightly enlarged posteriorly, not distinctly divided into two portions ....*Axonchium.*
k j Oesophagus distinctly larger posteriorly than anteriorly.............*Dorylaimus.*

Spear-bearing Genera at Present Known in Hawaii

Endoparasitic Genera:
- (1) Heterodera
- (2) Tylenchus
- (3) Aphelenchus
- (4) Isonchus
- (5) Dolichodorus
- (6) Hoplolaimus

Exoparasitic Genera:
- (7) Axonchium
- (8) Dorylaimus
- (9) Discolaimus
- (10) Ziphinema

Of the spear-bearing nematodes present in the Islands, a certain number are "endoparasitic," i. e., they actually inhabit the internal root structures and are enclosed by them; the others are "exoparasitic," i. e., they live external to the plant itself, but derive nourishment from its internal structures by means of the introduction of a hollow spear through which the vital fluids are sucked.

The genera most commonly met with and which are most destructive in their results are the genus *Heterodera* and the genus *Tylenchus.*

1. *Heterodera:* This genus presents two species:
   - (a) *Heterodera radicicola.*
   - (b) *Heterodera schachtii.*

Both species are frequent in their occurrence and produce root lesions of a very characteristic type.

Heterodera radicicola: For a number of years *Heterodera radicicola* has been recognized in these Islands as a sugar cane parasite and was first placed on record by Dr. N. A. Cobb in 1909.

This nematode is very prevalent, widely distributed, and is an "endoparasite" of some virulence. The taxonomic characters are of interest as this species bears a close resemblance to *Heterodera schachtii* and to several of the *Tylenchus* group.

This nematode is unusual in that it produces a characteristic gall formation in the root substance. These form irregularly rounded swellings of variable size, readily visible to the observer and usually situated at the root terminations.

Heterodera schachtii: This species does not give rise to a genuine gall formation. Instead, there is a more uniform thickening of the entire root structure usually some little distance above the peripheral terminations. Associated with this is a marked proliferation and massing together of the collaterals. These also may show an individual spindlar enlargement depending upon the age and degree of the infestation. It is worthy of mention that in sugar cane and in pineapples

the gravid females of *Heterodera schachtii* are actually "endoparasitic" and not merely external parasites, as has been demonstrated in the usual infestation of beet root, etc. Only one other instance of this is on record, viz., a case of beet infection in Algiers when the *Heterodera schachtii* was found as an internal parasite.

2. *Tylenchus:* Of the genus *Tylenchus,* the species (a) *Tylenchus similis* is by far our greatest enemy both in the numbers present and in the extreme seriousness of the effects produced. *Tylenchus similis* is a true parasite inhabiting the internal root structures both cortex and stele, if it so desires.

These nematodes appear to prefer young and healthy root systems, the infestation usually reaching its maximum in cane between 4 to 10 months of age.

By means of its spear, the nematode punctures the external root coverings, enters the cortex and embeds itself in the cellular structures. Its point of ingress is marked by a slight red discoloration and as the infection proceeds, this deepens in intensity and increases in area, eventually giving rise to the dark reddish wine-colored lesions characteristically associated with the diseased conditions produced by *Tylenchus.*

At least three other species of *Tylenchus* have now been recognized infesting our cane roots. Of these (b) *Tylenchus Olaae* was described by Cobb in 1909, but as yet no adequate description has been found for the other two which have been temporarily designated the spiral *Tylenchus* and the small *Tylenchus.*

(c) *Tylenchus (spiral):* This is a nematode of some size, prevalent both in cane and pineapple roots. This nematode possesses the characteristics typical of the *Tylenchus* group and assumes a curious curved attitude peculiar to no other nematode which has come under our observation. The root lesions are similar to those of *Tylenchus similis.*

(d) *Tylenchus (small):* A small species of the genus *Tylenchus* and found inhabiting the roots of the sugar cane usually near the tips. This species is less prevalent than others of the same genus, but it has been demonstrated in several localities and gives rise to reddish discoloration and puncture lesions resembling those of *Tylenchus similis.*

3. *Aphelenchus:* A genus of spear-bearing "endoparasites" closely resembling the *Tylenchus group.* The spear is smaller than in *Tylenchus* and there is no posterior oesophageal bulb. This genus is widely distributed and is usually found together with *Tylenchus similis,* deeply embedded in the root substance some little distance above the tip.

4. *Isonchus:* Another genus closely resembling *Tylenchus* but possessing a spear devoid of basal bulbs. This genus is found in sugar cane and pineapples, and is usually in intimate association with *Tylenchus similis.*

5. *Dolichodorus:* A spear-bearing genus bearing a close resemblance to the *Tylenchus* group. This genus has been found in the sugar cane in Hawaii, but as yet has not been demonstrated in the cane of the other Islands.

6. *Hoplolaimus:* An "endoparasite" of small size and possessing very characteristic transverse striations and a powerful spear. This genus is widely distributed throughout the Islands and is most frequently found in soil in the immediate vicinity of the roots. On several occasions, members of this genus have been

found inhabiting an otherwise actively functioning root and must therefore be considered as true "endoparasites."

The "exoparasitic" nematodes though of somewhat less importance are yet worthy of consideration. They include a number of genera and occasion a fair proportion of plant disease. The method of attack is somewhat different in the case of the "exoparasite." In this instance, the nematode remains external to the plant, introducing only the sharply pointed hollow spear which penetrates the root cortex and by means of which the plant juices are extracted.

Regardless of the harm due to the lesion, its potential significance cannot be forgotten as it affords an open door for all organismal entrance, suitable environment for proliferation and favorable conditions for the production of disease.

Of the genera present in these Islands and attacking the sugar cane, the genus *Axonchium* is perhaps that most frequently met with.

7. *Axonchium:* This genus includes several species and is found universally distributed throughout the Islands. Occasionally members of this genus may be found actually inhabiting the internal root structures, but, owing to the invariable accompaniment of some degree of root decay, this infestation is believed to be accidental and therefore this genus is regarded as a true "exoparasite."

8. *Dorylaimus:* A genus closely resembling *Axonchium* and widely distributed throughout the Islands. This genus includes a number of different species and gives rise to the generalized lesions usually ascribed to *Axonchium*, etc.

9. *Discolaimus:* Another genus closely allied to *Axonchium* and *Dorylaimus.* It gives rise to lesions similar to those produced by the former and is distinguished from them by structural characters.

10. *Ziphinema:* Another genus of the "exoparasitic" group found widely distributed throughout the Islands. The injuries to the root system resemble those of *Axonchium* and others. This nematode is outstanding by reason of the exceptional length of its relatively slender trilobed spear. It has been demonstrated around the roots of cane and various other plants on Oahu and on Maui, but its relative scarcity makes it of minor economic importance.

Potash at Honokaa

[We give herewith data supplied us by the Honokaa Sugar Company and Pacific Sugar Mill on the results of one of their plant food experiments. These results show clear-cut gains for potash. On studying the plot yields one will note that, with but one exception, the plots getting potash gave juices with a better quality ratio than adjoining plots getting nitrogen only. The average quality ratio of the potash plots was 12.01, while that of the nitrogen only plots was 12.65.

Results of the same nature were reported from Ewa Plantation Company in a number of their potash experiments. We did not get this difference in our earlier potash tests, mainly along the Hilo coast.

This may have been due, in part at least, to the fact that in these earlier experiments we did not use as much potash as is now the case. In these earlier tests we generally used from 60 to 125 pounds of K_2O, as compared to amounts of from 200 to 400 pounds now being tried.—J. A. V.]

HONOKAA SUGAR COMPANY AND PACIFIC SUGAR MILL

Fertilizer Experiment No. 27, H. S. Co. Field No. 22 at 1,000 Ft. Elevation, Unirrigated Field. Crop 1926 Short Ratoons—16 Months Old When Harvested.

Summary of Results—Harvested August 31, 1926

Treatments Pounds per Acre	Q. R.	Tons per Acre Cane	Sugar	Gain	Loss
200 Nitrogen and 4000 Mill Ashes	13.23	47.88	3.62	.94	
200 Nitrogen	15.01	40.24	2.68		
200 Nitrogen and 200 P_2O_5	11.34	34.02	3.00	.17	
200 Nitrogen	13.41	38.00	2.83		
200 Nitrogen and 200 K_2O	14.25	44.19	3.10	.32	
200 Nitrogen	14.18	39.40	2.78		
200 Nitrogen, 200 P_2O_5 and 200 K_2O	11.99	39.01	3.25	.67	
200 Nitrogen	12.44	32.15	2.58		
200 Nitrogen, 200 P_2O_5 and 4000 Mill Ashes	9.77	37.92	3.88	.83	
200 Nitrogen	11.78	35.92	3.05		
200 Nitrogen and 8000 Mill Ashes	12.90	41.77	3.24	.56	
200 Nitrogen	13.29	35.64	2.68		
200 Nitrogen and 300 P_2O_5	13.68	36.85	2.69		.29
200 Nitrogen	12.32	36.69	2.98		
200 Nitrogen and 300 K_2O	12.54	42.23	3.37	.61	
200 Nitrogen	14.28	39.40	2.76		
200 Nitrogen, 300 P_2O_5 and 300 K_2O	12.22	48.99	4.01	.52	
200 Nitrogen	10.94	38.14	3.49		
200 Nitrogen, 300 P_2O_5 and 8000 Mill Ashes	10.74	37.75	3.51	.32	
200 Nitrogen	10.83	34.58	3.19		
200 Nitrogen, 400 P_2O_5 and 400 K_2O	10.44	49.47	4.74	.75	
200 Nitrogen	11.09	44.22	3.99		

In this field the cane of the previous crop showed much distress. Symptoms indicating the lack of potash were very pronounced throughout the field, and particularly in the lower lying areas. The figures as shown in the above results fully explain the trouble.

We note that phosphate at the rate of 200 pounds P_2O_5 per acre gives a small gain and 300 pounds P_2O_5 per acre an actual loss. This may be due to an unbalanced plant food when phosphate fails to play its role in the absence of a liberal amount of potash.

E. E. NAQUIN.

Methylene Blue Method for Glucose Determination

By W. R. McAllep

Volumetric glucose methods have been only moderately accurate because of the somewhat indefinite end point and inaccuracies due to the time required to filter off a portion of the solution for making the end point test. The methylene blue modification was proposed and worked out by Lane and Enyon* to remedy these defects. In this method, shortly before the end point is reached a few drops of methylene blue are added to the boiling solution giving it an intense blue color. When the last trace of copper is reduced the blue color disappears thus giving a very sharp end point.

This method has been used extensively at this Station for juice analysis. The results are more consistent than are ordinarily secured with gravimetric methods and much less time is required. We have not yet tried the method out thoroughly on molasses. The end point in molasses analysis is somewhat obscured by the color of the solution, but from what work has been done we believe that with practice the end point can be determined even in dark molasses solutions with a satisfactory degree of accuracy. The following directions are based on Mr. Cook's and Mr. Bomonti's experience with this method.

Solutions

1. Methylene Blue. Dissolve one gram of methylene blue and make up to 100 c.c. with water. Lane and Enyon state that they have not found much difference in samples of methylene blue from different sources. We have found some preparations sold as methylene blue unsatisfactory. The grade of methylene blue used for biological stains is suitable. We have found methylene blue U. S. P. medicinal, Schultz No. 659, put out by the National Analine and Chemical Company satisfactory.

2. Soxhlet's Solution. Prepare Soxhlet's solution as directed on page 21 of Methods of Chemical Control, 1923. This solution should be standardized and adjusted to exact strength as directed below.

3. Standard Invert Sugar Solution. The following solution proposed by Lane and Enyon is recommended: Weigh out exactly 9.5 grams of the purest refined sugar obtainable, add 5 c.c. of concentrated hydrochloric acid and make up to a volume of about 100 c.c. Allow to stand for two or three days if the temperature is as high as 20-25° C. or for a week if the temperature is as low as 12-15° C., then without neutralizing make up to one liter and keep in a well stoppered bottle. This solution is sufficiently acid to prevent the development of micro-organisms and will keep for considerable time. One hundred c.c. of this solution contains one gram of invert sugar.

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* Journal Society of Chem. Industry, 1923, pages 34T, 143T and 463T.

Standardization of Soxhlet's Solution

Take 50 c.c. of the invert sugar solution, prepared as above, in a 250 c.c. flask. Neutralize and make up to 250 c.c. with water. Titrate as described below under "Analysis." 25.64 c.c. of the solution should be required. Adjust the copper sulphate solution if necessary (Solution A) until it is of the proper strength. The alkali solution (Solution B) need not be adjusted if it is made strictly according to directions.

Preparing Samples for Analysis

The sucrose content of the sample must be known for this value is used in calculating the results. For ordinary tests on juices the difference between sucrose and polarization may be neglected. Directions given under "Preparation of Samples" on page 40, 1923, Methods, may be followed, except that the amount of sample and the dilution must be varied to suit the requirements of this test. The sucrose concentration in the sample prepared for analysis should not exceed 5 grams per 100 c.c. for this is the highest sucrose concentration in the accompanying table of factors. Preferably the glucose concentration should be such that 25-40 c.c. of the solution, corresponding to 125 to 200 milligrams of glucose per 100 c.c. is required for the titration.

If the approximate glucose content is unknown a preliminary titration should be made. Suitable quantities for a preliminary titration, usually approximating the above specifications are:

Juices, 50 c.c of original juice in 200 c.c. of prepared solution.

Final molasses, 2 grams in 200 c.c. of prepared solution, 10 grams of molasses clarified with neutral lead acetate, made up to 250 c.c. filtered and 50 c.c. of this filtrate deleaded with di-sodium phosphate and made up to 200 c.c. gives the above concentration.

Apparatus

An accurately graduated burette should be used for measuring out the copper solution (Solution A). A calibrated 5 c.c. pipette is sufficiently accurate for measuring out the alkali solution (Solution B). An accurately graduated burette should be used for delivering the prepared sugar solution. The test should be made in an Erlenmeyer flask. A 300 c.c. pyrex glass flask is recommended. A small electric hot plate is a more convenient source of heat than a burner. It is advisable to cover the burner or hot plate with a piece of asbestos board in which a hole approximately the size of the bottom of the flask has been cut to protect the hands. If a flame is used the flask should rest on a wire gauze. A light wire test tube holder, which may be left attached to the neck of the flask, is convenient. A two-minute sand glass is very convenient for timing the boiling.

Analysis

First make a preliminary titration to determine the approximate amount of sugar solution required to reduce all the copper, following in general the directions given below. In the preliminary test add a considerable proportion of the sugar solution before boiling and do not add the methylene blue until near the end point.

Deliver exactly 5 c.c. of the standardized copper solution into the Erlenmeyer flask, add 5 c.c. of the alkali solution. Water must not be added, for dilution will give erroneous results. Then add to within 1 c.c. of the amount of sugar solution required to completely reduce the copper. Bring to boiling and boil for exactly two minutes. Add five drops of the methylene blue solution preferably with a medicine dropper. Without removing the flask from the heat or interrupting the boiling, add the sugar solution cautiously from the burette, held in the hand, until the end point is reached, taking not over one minute to complete the titration. The total time of boiling must be three minutes. After each addition of sugar solution the flask should be given a rotary motion without removing it from the flame or stopping the boiling. The solution should be kept boiling rather vigorously throughout the test to keep the flask as free from air as possible. A very slight contact with air will reoxidize the methylene blue and give erroneous results.

End Point

The end point is very sharp but as it is somewhat obscured by the reduced copper in the boiling solution it is sometimes difficult at first to detect it with certainty.

When the methylene blue is added it colors the contents of the flask a deep blue. The color persists with but little change until all but a very small amount of the copper has been reduced, when it begins to fade. As the blue fades the yellow color of most sugar solutions will give the solution a greenish tint. A green color indicates a very close approach to the end point and two or three drops more are usually sufficient to complete the titration.

The color of the liquid can usually be seen best at the edge of the solution. While learning to judge the end point the flask may be removed for an instant. When the copper begins to settle the color of the solution can be seen clearly. This is a dangerous practice and is not recommended for regular work, for as soon as boiling stops, air is liable to enter the flask and reoxidize the methylene blue. However, it is possible to stop the boiling for an instant without seriously interrupting the flow of steam from the flask.

As the blue color fades the color of the reduced copper appears brighter and after the blue color is discharged does not change further. This appearance can be recognized. After experience has been gained, the greenish tint denoting the close approach to the end point, the disappearance of the green tint particularly at the edges of the solution and the characteristic appearance of the copper precipitate enables the exact end point to be located with little if any uncertainty.

The end point of this test is so sharp that at least in juices, the accuracy with which solutions are made up and measured out, and how closely the directions for conducting the test are followed will usually be the limiting factors in the accuracy of the results rather than detecting the exact end point.

Excessive frothing interferes with detecting the end point and increases the danger of back oxidation. When solutions froth excessively rub a very small amount of vaseline inside the neck of the flask. On melting this will run down and reduce the frothing sufficiently so that the end point is not obscured. This does not affect the results.

Calculation of Results

Look up the factor corresponding to the c.c. of sugar solution used, in the column corresponding to the sucrose concentration of the prepared solution, interpolating between columns if necessary. Dividing this factor by the c.c. of sugar solution used and multiplying by a hundred gives the glucose, calculated as invert sugar, in the solution prepared for analysis in mg. per 100 c.c. From the weight of the original sample in 100 c.c. of the prepared solution and the milligrams of invert sugar per 100 c.c. calculate the per cent of glucose in the original sample.

Example: The juice is 12 Brix and 10 per cent sucrose. In preparing this sample for analysis the dilution is such that 100 c.c. of the prepared solution contains 25 c.c of the original sample. The sucrose concentration of the prepared solution is therefore 2.5 grams per 100 c.c. On titration it is found that 30.0 c.c. of the solution is required.

Interpolating between the 2 and 3 gram columns we find the factor is 49.4.

$$\frac{49.4 \times 100}{30} = 164.7 \text{ milligrams glucose per 100 c.c. of prepared solution.}$$

100 c.c. of the prepared solution contains 25 $\times$ 1.10505 (the specific gravity corresponding to 12.0 Brix) = 27.63 grams of the original sample.

$$\frac{.1647 \times 100}{27.63} = 0.596 \text{ per cent glucose.}$$

FACTORS: METHYLENE BLUE VOLUMETRIC GLUCOSE METHOD

The factor divided by the c.c. of sugar solution used × 100 gives milligrams of glucose per 100 c.c. when 5 c.c. each of Soxhlet's Solutions A & B are used

C.C. Sugar Solution	Sucrose per 100 c.c. of Sugar Solution 0	.5 Gram	1 Gram	2 Grams	3 Grams	4 Grams	5 Grams
15	50.5	50.2	49.9	49.4	48.8	48.3	47.6
16	50.6	50.3	50.0	49.4	48.8	48.3	47.6
17	50.7	50.4	50.1	49.4	48.8	48.3	47.6
18	50.8	50.4	50.1	49.4	48.8	48.3	47.6
19	50.8	50.4	50.2	49.5	48.9	48.3	47.6
20	50.9	50.5	50.2	49.5	48.9	48.3	47.6
21	51.0	50.6	50.2	49.5	48.9	48.3	47.6
22	51.0	50.6	50.3	49.5	48.9	48.4	47.6
23	51.1	50.7	50.3	49.6	49.0	48.4	47.6
24	51.2	50.7	50.3	49.6	49.0	48.4	47.6
25	51.2	50.8	50.4	49.6	49.0	48.4	47.6
26	51.3	50.8	50.4	49.6	49.0	48.4	47.6
27	51.4	50.9	50.4	49.6	49.0	48.4	47.6
28	51.4	50.9	50.5	49.7	49.1	48.4	47.7
29	51.5	51.0	50.5	49.7	49.1	48.4	47.7
30	51.5	51.0	50.5	49.7	49.1	48.4	47.7
31	51.6	51.1	50.6	49.8	49.2	48.5	47.7
32	51.6	51.1	50.6	49.8	49.2	48.5	47.7
33	51.7	51.2	50.6	49.8	49.2	48.5	47.7
34	51.7	51.2	50.6	49.8	49.2	48.5	47.7
35	51.8	51.3	50.7	49.9	49.2	48.5	47.7
36	51.8	51.3	50.7	49.9	49.2	48.5	47.7
37	51.9	51.3	50.7	49.9	49.2	48.5	47.7
38	51.9	51.3	50.7	49.9	49.2	48.5	47.7
39	52.0	51.4	50.8	50.0	49.2	48.5	47.7
40	52.0	51.4	50.8	50.0	49.2	48.5	47.7
41	52.1	51.4	50.8	50.0	49.2	48.5	47.7
42	52.1	51.5	50.8	50.0	49.2	48.5	47.7
43	52.2	51.5	50.8	50.0	49.3	48.5	47.7
44	52.2	51.5	50.9	50.0	49.3	48.5	47.7
45	52.3	51.5					
46	52.3	51.5					
47	52.4	51.6					
48	52.4	51.6					
49	52.5	51.7					
50	52.5	51.7					

The History and Distribution of Eye Spot

By H. Atherton Lee

Eye spot is one of the oldest infectious diseases of sugar cane for which there is any authentic record. As early as the year 1892, eye spot was described in Java. A colored illustration and a more complete account of the appearance of the disease in Java were published in 1898 by the two investigators, Wakker and Went (7); this plate, illustrating the nature of the disease, shows it to be identical with eye spot of the Hawaiian Islands.

Apparently the cane varieties grown on a plantation scale in Java have been, with one or two exceptions, resistant to eye spot, and the disease has not been considered important there.

Eye Spot in Other Countries

Eye spot is also widely distributed in many other cane-growing countries. It is known in India, the Philippines, Formosa, Cuba, Porto Rico, Jamaica, Barbados, Trinidad, Santo Domingo and Reunion, as well as Java and the Hawaiian Islands. In these other countries, also, varieties which are resistant to eye spot have been commonly grown and the disease has not been considered serious.

More recently, however, in Porto Rico eye spot is occasionally bad on new seedling varieties which have high susceptibility to the disease (Cook 3). Miss Wilbrink, the cane pathologist of the Java Sugar Experiment Station, stated in conversation that she also observed the disease severely attacking new seedlings in Santo Domingo, and H. P. Agee stated that he observed the disease occurring severely in several areas in Florida. There is one instance of an outbreak in Java; Miss Wilbrink told of an outbreak one year on the variety P. O. J. 100 which was very severe in one district; however, the disease did not recur. It is apparent that with the extension of new seedling varieties, eye spot is receiving more attention than it has in the past in other cane growing countries.

Fire Blight or Top Rot in Early Days in the Hawaiian Islands

In the Hawaiian Islands as early as the year 1854 there was an account of a serious disease called "fire blight," at Lihue, Kauai. The account of this disease was contained in the annual address by the Honorable William L. Lee (5), president of the Royal Hawaiian Agricultural Society, in June, 1854. Extracts of this address are as follows:

> The last year's crop has not equalled our expectations, though it has exceeded that of the year before. We estimate the whole produce of the islands for the last season at 800 tons, which, with the syrup and molasses, is valued at $120,000. The present crop of the Koloa Plantation, on Kauai, owned by Dr. R. W. Wood and Mr. Burbank, will amount

to 300 tons of beautiful sugar, which, at six cents per pound, makes the handsome sum of $36,000. Its syrup and molasses I estimate at ten thousand dollars more, which shows a total of $46,000. The whole expenses of the plantation per annum do not exceed, I am told, fifteen thousand dollars. Comment is unnecessary.

The Lihue Plantation, owned by Henry A. Pierce & Company, only ten miles distant from that of Koloa, has been less favored. Owing to causes which no human agency could avert, the large crop anticipated has proved an almost complete failure. A year ago last December the prospects at Lihue were cheering in the highest degree, and we were sure that we should harvest a crop this season of at least 400 tons. The sun never shone on finer fields of cane. In January a storm came, accompanied with terrible thunder and lighting, and blasted our smiling fields as with the breath of fire. After the storm passed, the cane fields grew brown, rotted and died, and 400 acres that should have brought us at least $50,000, hardly produced one-sixth part of that sum.

The whole crop did not exceed fifty tons. The cause of this fire blight is still a mystery. At first we thought that it might be the work of an insect, but the closest examination showed that we were mistaken, and we can ascribe it to nothing but some great convulsion in the atmosphere.

The account of this "fire blight" answers in many ways to a description of eye spot. The fields were green in December, but following rains in January the fields became brown. The disease did not occur at Koloa with its southern exposure, but at Lihue with its eastern exposure and ridges of hills shutting off sunlight and air movement the disease broke out. This is similar to eye spot occurrences at the present time. It is shown by the previous annual report of the Royal Hawaiian Agricultural Society that a small lot of "Tahiti" cane had just been introduced at Lihue, and it seems probable that this was another introduction of the cane which subsequently became known as Lahaina. In this case it would seem that Lahaina cane had not been widely planted at Lihue in 1854, which would mean that some of the native varieties were being grown then on a plantation scale at Lihue. L. D. Larsen, manager of Kilauea Sugar Plantation Company, and formerly pathologist at the Experiment Station, concurs in this view and states that in previous years, working on eye spot, he found that several of the native canes were extremely susceptible.

Of the infectious diseases which occur in these Islands at the present time, the account of this fire blight in 1854, is most descriptive of eye spot.

In the early days at Waialua, W. W. Goodale, in conversation, states that eye spot was called top rot. The disease was known there at a very early date and in 1904 or 1905, several fields growing the Lahaina variety were so severely attacked that the cane was plowed out and the fields planted in other crops.

Lewton-Brain (6), of this Experiment Station, in first describing eye spot as a known infectious disease of these Islands, in 1907, mentioned that the disease had been previously called rust. It seems very probable, therefore, that eye spot has existed in the Hawaiian Islands for many years although the well established records of the disease under the name "eye spot" only date to 1907.

Investigations on the Cause of Eye Spot

The fungus causing eye spot was first described by the Dutch investigator Van Breda de Haan (1) in the year 1892; he described the fungus as *Cercospora*

sacchari. He also tried infection tests and was able to reproduce the disease by inoculation of the leaf blades of sugar cane with the spores of this fungus, thus establishing the causal relationship of the fungus to the disease.

Mr. Larsen (4), in 1912, isolated the same fungus in pure cultures, from the disease in the Hawaiian Islands, and was able to reproduce eye spot on cane plants by spraying the leaves with an infusion of the spores from such cultures. This confirmed the work of Van Breda de Haan in Java.

In India the causal fungus was described in the year 1913 by the English investigator, Butler (2), independently of the Java workers; Butler placed the fungus in the genus *Helminthosporium* and called it *Helminthosporium sacchari,* instead of *Cercospora sacchari.* The nomenclature of Butler is usually followed by investigators at the present time. Butler also carried on infection tests and reproduced the disease with the eye spot spores, so that it is established beyond question that the agent causing eye spot is the fungus *Helminthosporium* (*Cercospora*) *sacchari.* At the present time, given proper atmospheric moisture we are able to reproduce eye spot at will by spraying plants with infusions of the eye spot fungus.

The Present Outbreak of Eye Spot in These Islands

During the past twenty years, the varieties widely grown in these Islands have not been highly susceptible to eye spot; Rose Bamboo, Yellow Caledonia, Striped Mexican, D 1135, Badila and the Tip canes are all very highly resistant to this disease; Lahaina has been much less susceptible than H 109.

In 1910, in *The Hawaiian Planters' Record* is a statement concerning eye spot and ring spot as follows: "There is little possibility that in our climate they will be able to kill the cane outright. The great danger from these diseases is that, attacking the cane as they do when the weather conditions are unfavorable to its growth, they may so reduce its vitality that some aggressive fungus will be able to carry it off."

However, eye spot has been creating increasing attention since then.

In 1911, Mr. Larsen stated: "On two of the plantations (on Oahu) eye spot was found to be quite severe. . . . " In the same year, in an editorial in *The Planters' Record,* it was stated: "Eye spot (on Maui) was found wherever Lahaina cane was grown and was reported as a disease of no inconsiderable importance. It was said to be most severe during the months of February and March, and to disappear entirely with the warm weather in May and June. As a general rule it was found to be more severe on new land than in fields which had been under cultivation for any length of time."

It is only with the extensive spreading of H 109, with its high susceptibility to this one particular disease, that eye spot has become an important factor in plantation practice in some localities in these Islands. The increase in eye spot infection in these areas has, moreover, been cumulative with the spread of H 109, for with the increase in H 109 there have consequently been greater sources for infection and spread of the disease. The increase in eye spot in certain localities seems to be, therefore, not due to an increase in virulence of the fungus so much

as to the great spread of a susceptible cane variety and a corresponding great increase of sources of infective material, i. e., eye spot spores.

This brief history brings the subject to the present time, when efforts are being made to combat eye spot in these Islands by obtaining resistant varieties equally as productive as H 109 for the affected areas, or, without sacrificing H 109, by field practices to minimize or prevent eye spot.

Summary

(1) A disease called "fire blight" did much damage to cane in the Hawaiian Islands as early as the year 1854, and the description of "fire blight" agrees in many ways with the appearance of eye spot.

(2) The first well established record of eye spot was in 1892 in Java; the first well established record in the Hawaiian Islands was in 1907.

(3) Eye spot is widely distributed in many countries and occurs in India, the Philippines, Formosa, Cuba, Porto Rico, Jamaica, Barbados, Trinidad, Santo Domingo and Reunion, as well as Java and the Hawaiian Islands.

(4) A fungus as the cause of eye spot was first established in Java in the year 1892, and the fungus was called *Cercospora sacchari* by the Dutch investigator Van Breda de Haan. Larsen, in the Hawaiian Islands, confirmed the work of Van Breda de Haan, establishing a fungus as the cause of eye spot. Butler in India, independently of these other workers, established the same fungus as the cause of eye spot, but placed its systematic position differently, placing it in the genus *Helminthosporium* as *H. sacchari.* The nomenclature *Helminthosporium* (*Cercospora*) *sacchari* Butler is now in general usage by investigators.

(5) Only in the last few years has eye spot become an important factor to be contended with in cane growing in the Hawaiian Islands. This is due to the extensive planting of the susceptible variety H 109 in situations favorable for eye spot development. The spread of H 109 in such situations favorable for eye spot has not only meant more eye spot, but more sources of infection for the spread of the disease.

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Description of Eye Spot as Compared With Other Sugar Cane Leaf Spot Diseases

By H. Atherton Lee and J. P. Martin

During the past few seasons reports of the occurrence of eye spot have sometimes been received, and on investigation it has been found that other less serious diseases have been confused with eye spot. The following is a brief description which may aid in distinguishing eye spot from other diseases.

Standard Varieties Affected

The varieties affected serve to aid in distinguishing eye spot from other diseases. Yellow Caledonia, Badila, Striped Mexican and Uba are so seldom affected that one can usually be sure that large spots and reddish streaks found on these varieties are not eye spot. When these varieties occur in the midst of a field of a susceptible variety, they will sometimes be infected, but the spots produced are so small that they usually will not be noticed and there will be no red streaks spreading from the original infections.

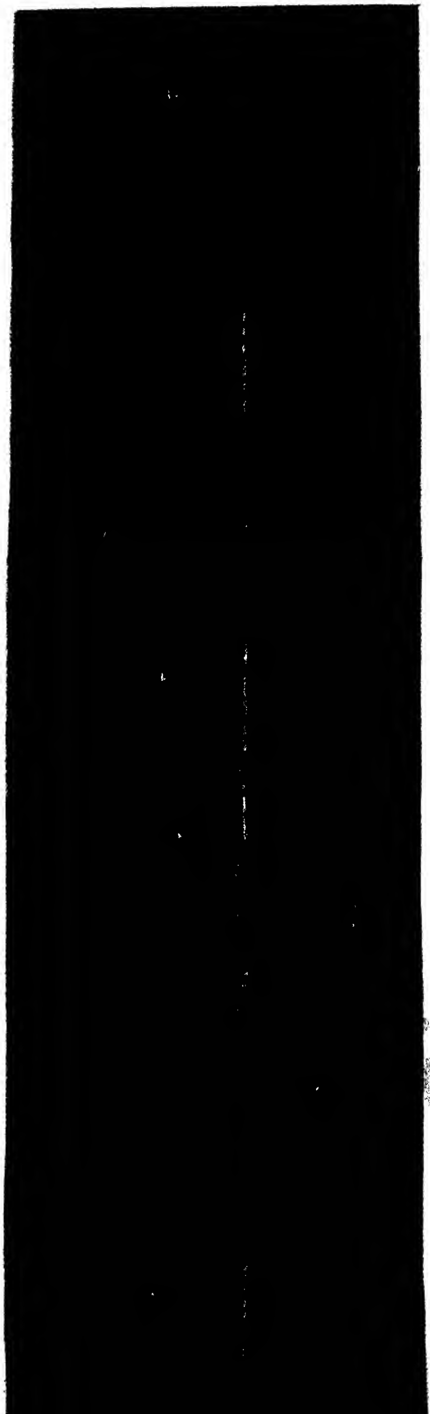
D 1135 and the Tip canes are seldom affected, but when planted adjacent to a susceptible variety they occasionally become infected. The spots produced on these varieties are usually of a good size and readily noticeable, and in appearance are similar to early infections on H 109 or Lahaina.

On all varieties eye spot affects the younger leaves. The other leaf spot which is usually confused with eye spot is ring spot. Whereas, eye spot affects the younger leaves, ring spot is found only on the older leaves; this alone is an easy way to aid in distinguishing eye spot from other leaf spots in the Hawaiian Islands.

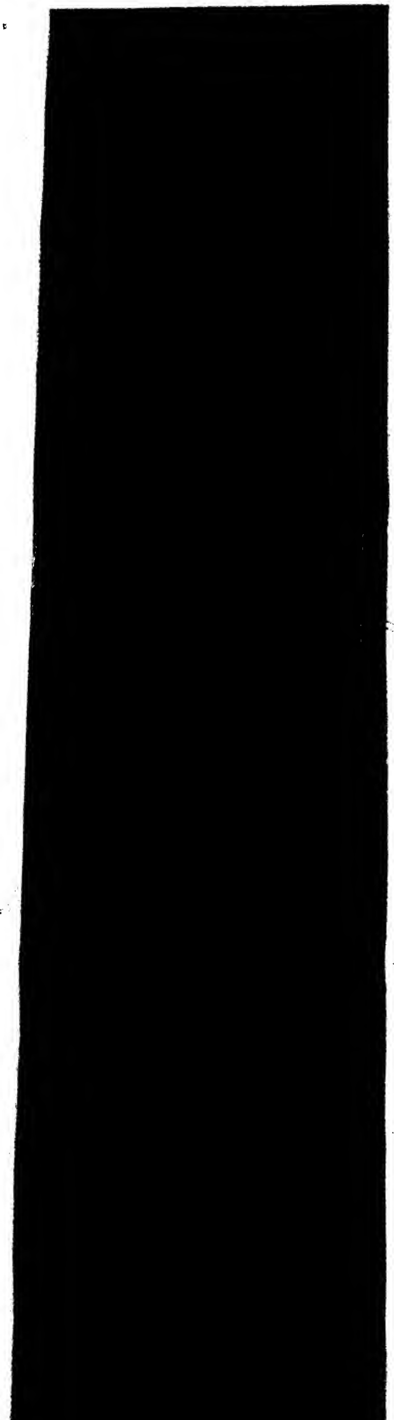
Of the standard varieties grown in the Hawaiian Islands, H 109 and Lahaina are the most commonly affected. Reddish spots on the younger leaves of these two varieties, which extend into long yellow or reddish streaks, are almost certainly eye spot infections. A more detailed description of eye spot follows:

Detailed Description of Eye Spot in the Variety H 109

The first indications of the development of a lesion are noticed when a small oblong spot shows on the leaf, of a watery, darker green than the normal leaf, and from one-eighth to one-fourth inch long and one-sixteenth inch or thereabouts in width. This stage shows up immediately after infection of the leaf by



Ring Spot



Eye Spot

the fungus, and may appear on either upper or lower surfaces of the leaf; it will rarely be noticed in the fields under usual plantation conditions.

After three or four days, such a dark green area becomes a pale yellow, straw-colored oval lesion, visible on both upper and lower surfaces of the leaf, one-fourth inch to three-eighths inch in length. This yellow area gradually enlarges and after seven or eight days reddish-brown oval spots appear in the center of the yellow spots; the yellow areas make a sort of halo-like appearance about each red spot. The longest axis of the spots is in the direction of the length of the leaf. The yellow halo then begins to elongate into a streak running upwards on the leaf; this streak is at first yellow but then becomes a reddish-brown. Occasionally streaks may extend downward on the leaf for a short distance, but the majority of streaks run upward; they may be from one-eighth to three-eighths inch in width. Such streaks sometimes reach a length of 18 to 36 inches. Where very many eye spot lesions occur on the same leaf, these streaks coalesce and cause the whole leaf to become a reddish-brown color and the leaves die back from the tips and edges; where this condition becomes general on many plants the field as a whole assumes a reddish-brown appearance, for which the name "fire blight," used in the old days, was very appropriate.

The original oval spot, which became visible before the streak formed, often dies in the center and there is then a slender oval dead area of leaf which is a pale brown or ashen color, inside of the red ring. The yellow halo surrounding the red spot has often disappeared at this stage.

Where a leaf becomes badly infected and many long reddish streaks are formed, the young, newly formed leaves in the central cylinder also often become badly infected and the infection runs down into the top of the cane and a top rot results. Such a top rot is the worst effect of eye spot. The leaf blade is principally attacked; the midrib is rarely attacked, if at all, in the case of H 109, and the leaf sheath also is rarely attacked. Occasionally, in severe cases, the cane stalk itself is attacked and such lesions on the stalk appear to permit the ingress of other stalk-rotting organisms and they cause severe injury.

In the Hawaiian Islands there are but two diseases, ring spot, mentioned previously, and red stripe, which could readily be confused with eye spot. Eye spot and ring spot have readily obvious differences. Eye spot is more reddish in color than ring spot, which is brown. Ring spot never runs into a long narrow streak as does eye spot. As mentioned previously, also, eye spot attacks the younger leaves, whereas ring spot attacks the older outside leaves. These differences are shown much more clearly in the accompanying colored illustration by Potter than is possible to bring out in a written description.

Red stripe disease results in a long streak of a dark purplish-red color and has very even regular edges. The reddish streaks of eye spot are lighter colored and more brownish than those of bacterial red stripe. Eye spot streaks, moreover, have very irregular indefinite edges often with yellow areas along the edges not seen in red stripe disease. Red stripe does not affect Lahaina or H 109 and is very common on the Tip canes, whereas, as mentioned previously, eye spot rarely attacks the Tip canes, but is very common on Lahaina and H 109 varieties.

Losses Caused by Eye Spot

By H. Atherton Lee

Different Types of Injury

When but one or two eye spot lesions occur to a leaf in a cane field, the injury to the cane is scarcely noticeable. However, often the leaves may show 20 or 30 eye spots, and such a large number causes the leaf to become entirely brown and of no value in functioning for the plant. This type of leaf injury shows, a few months later, in the cane stick, which will be much reduced in diameter and the joints much reduced in length. In such cases of heavy leaf infection there is also a slightly deleterious effect upon the juices of the cane.

The worst injury from eye spot, however, results from top rot, which is brought about by very heavy infection of the young new leaves in the central cylinder or spindle of the cane top. When these very young leaves become heavily infected the killed area often extends down into the growing bud of the cane and top rot results.

After such top rot the cane may produce lalas, but very often secondary fungi follow the top rot and invade the sound stalk below the top, resulting in total loss of the cane stick.

Most eye spot areas do not reach the top rot stage. The field areas with heavy leaf infection are more widespread than those with the top rot stage, and the mildest degree of infection where but a single spot or two occurs per leaf is much more widespread and can be found on most plantations, causing, however, little or no loss.

Effect on the Cane Juices

Some figures on the deterioration in juices following top rot from eye spot are as follows. These data have been furnished by Mr. Larsen, manager of Kilauea Plantation, and are the most comprehensive to date, being in carload lots:

	Car No.	No. of Cane Sticks	Per Cent of Total	Total Weight Net	Weight per Stick	Juices: Brix	Juices: Pol.	Juices: Pur.	Juices: Q. R.	Total Sugar	Sugar per Stick
Healthy	98			2418							
	204			2473							
		1230	54.42	4891	3.977	20.79	18.79	90.4	7.0	698.8	.5682
Tops dead from eye spot	294	400	17.80	848	2.12	16.19	12.16	75.1	12.56	67.52	.1688

In the above test Mr. Larsen had the cane brought in from the field in the cars, with the tops on. At the factory, he personally separated healthy sticks from sticks with top rot following eye spot. There was a third class which he

separated, the tasseled sticks, but these are not reported in the above table since Mr. Larsen will present the tasseling results in person.

A similar test from another field affected with eye spot gave the results tabulated by Mr. Larsen as follows:

Class	No. of Cane Sticks	Per Cent of Total	Total Weight Pounds	Weight per Stick	Juices Brix	Juices Pol.	Juices Pur.	Q. R.	Total Sugar Pounds	Sugar per Stick Pounds
Healthy	400	33.32	1776	4.44	19.92	17.98	90.2	7.4	240	.60
Dead or partly dead from eye spot	200	16.67	591	2.95	17.02	14.53	85.3	9.4	63	.31

We have other data which agree with the above, showing that cane affected with top rot following eye spot has much poorer juice qualities than unaffected cane, as well as lessened weight.

Acreage Affected and Losses Incurred in the 1926 and 1927 Crops

Eye spot is usually most severe on the first season's growth and does not usually affect mature cane severely; it is, therefore, possible to present the figures for the acreage of H 109 affected in the 1927 crop as well as the 1926 crop.

In the following table is a compilation of the acreage of H 109 affected with eye spot, and estimates of the losses incurred throughout the Islands. The figures for the acreage affected are fairly accurate but the figures for the losses incurred have a value only as estimates. It is, nevertheless, obvious that a good estimate of losses is much more definite than no figure whatsoever. Both the acreage involved and the estimates of losses have been worked out in close cooperation with the plantation skilled staffs so that they represent the plantation views as well as our own.

EYE SPOT LOSSES BY ISLANDS—1926 CROP

Island	Acreage of H 109	Acres With Eye Spot Injury	Percentage of H 109 Acreage	Acreage of All Varieties	Percentage of Total Acreage	Estimated Losses Tons Sugar	Percentage Loss on Crop
Oahu	20,615	880	4.2	23,522	3.7	613	0.28
Kauai	10,438	650	6.2	22,276	2.5	485	0.37
Maui	14,550	0	0.0	20,001	0.0	0	0.00
Hawaii	580	0	0.0	52,483	0.0	0	0.00
Totals	46,183	1,530	3.3	118,282	1.3	1,098	0.14

Total 1926 crop estimated at 772,000 tons (figures from A. M. Nowell, Manager of Sugar Factors Company, Ltd.).

EYE SPOT LOSSES BY ISLANDS—1927 CROP

Oahu	18,645	849	4.5	21,094	4.0	612
Kauai	10,227	1,173	11.4	23,516	4.9	846
Maui	16,277	0	0.0	20,077	0.0	0
Hawaii	602	0	0.0	51,775	0.0	0
Totals	45,751	2,022	4.4	116,462	1.7	1,458

In the foregoing tabulations, the acreages of H 109 are taken from the 1926 Acreage Census (Experiment Station, H. S. P. A., Circular 46, by J. A. Verret). When the acreages of the 1926 crop are tabulated it is seen that only 3.3 per cent of the H 109 acreage was affected with eye spot, leaving 96.7 per cent of the H 109 acreage which was not injured. Of the total acreage of all varieties, 98.7 per cent is free from injury due to eye spot. In the 1927 crop, 4.4 per cent of the H 109 acreage was affected, showing that there was an increase of the disease.

Although the compilations (the estimates for the 1926 crop, 772,000 tons, were obtained from A. M. Nowell, manager of Sugar Factors Company) show a loss in yields of the 1926 crop to the industry as a whole of only 14/100ths of one per cent, it does not entirely represent the situation. The 1927 crop had considerably increased acreage affected, even under the conditions of last winter, which were considered adverse for eye spot. If the coming winter is favorable for eye spot our losses will be very much greater, due to the large sources for the spread of infection which are being carried over this summer. Moreover, although the industry as a whole does not suffer severely, to those few plantations that are affected eye spot is a matter of vital importance. Still another factor to consider is, that with the large acreages of H 109 there is an increasing amount of eye spot, and consequently larger and more sources of infection for the spread throughout previously unaffected fields and to previously unaffected plantations.

Our feeling is that we are worried about eye spot on a few plantations, but that for the Islands as a whole there is no need for alarm. Nevertheless, there is need for earnest endeavor to cut down these losses and prevent spread of the disease.

The Effect of Drying on the Spores of the Eye Spot Fungus

By J. P. Martin and H. Atherton Lee

Some micro-organisms are readily killed by exposure to dry air; as an example, the bacteria of red stripe disease of sugar cane die out completely in twenty-four hours when exposed in thin infusions to the dry air of a cloudless day at the Experiment Station. In the case of eye spot under field conditions, there is a natural diminution of the disease usually beginning in March and almost completely disappearing in June; knowledge of how the spores of the eye spot fungus endure the dry-air conditions of cane fields after this disappearance of the disease in June, until the following October, enables one to attempt preventive methods more intelligently. The following is an account of experiments in which the resistance was tested of the spores of the eye spot fungus to dry air conditions.

Method

Twenty-five covered culture dishes, each dish containing ten small circular cover glasses, were sterilized. An infusion of the eye spot spores was prepared in sterile water and a drop of such infusion was placed on each cover glass under aseptic conditions. Each drop contained from 20 to 25 spores of the eye spot fungus. The culture dishes containing the cover glasses were then placed in a chamber in which the normal atmospheric conditions of the laboratory existed but where possibilities of contamination from dust were much minimized. At given intervals during the drying period, 5 or 10 of these inoculated cover glasses were removed from the culture dishes and placed, under aseptic conditions, in tubes of liquid culture medium; nutrient bouillon was used for the culture medium. If the fungus spores still lived after the drying, growth of the eye spot fungus occurred in the bouillon tubes, while if the spores were killed by the drying the bouillon tubes showed no growth.

The experiment was repeated and the results of both tests are shown in the following table:

TABLE I

SHOWING GROWTH RESULTING FROM EYE SPOT SPORES AFTER PERIODS OF EXPOSURE TO DRY AIR CONDITIONS

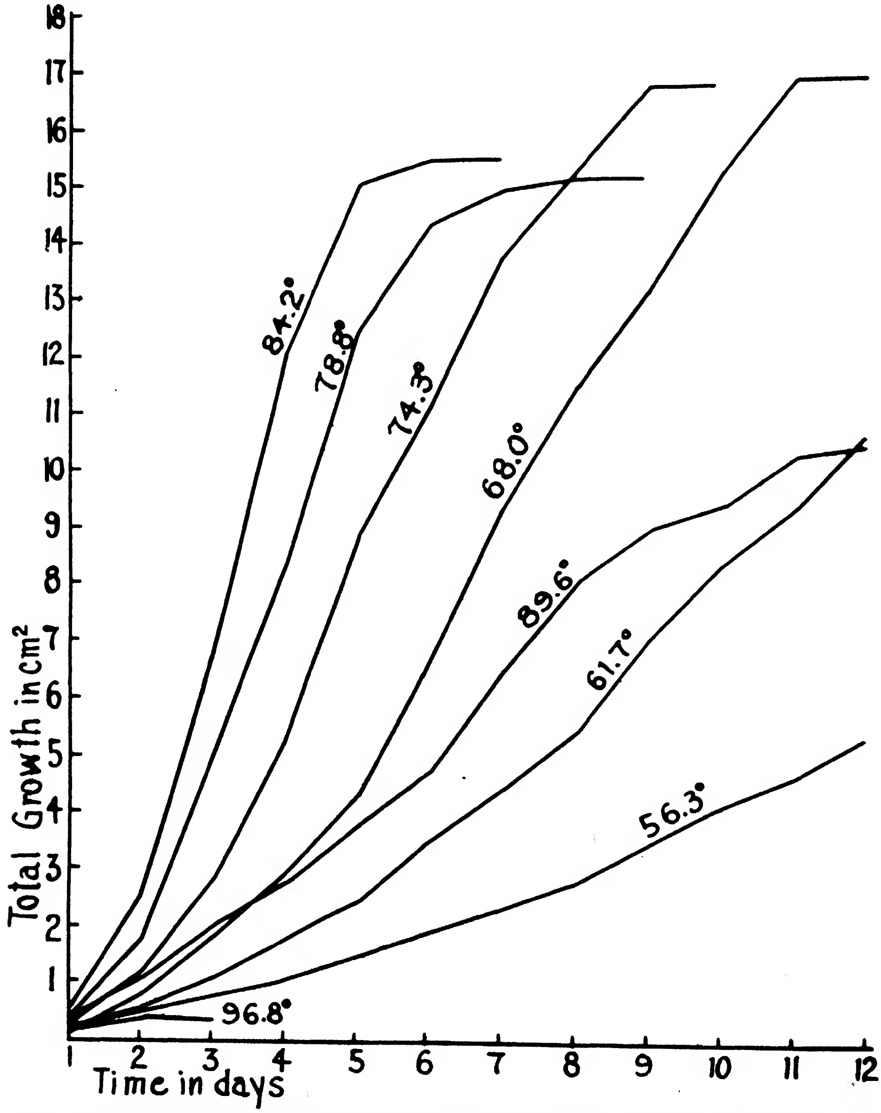
Interval of Exposure to Drying in Hours and Days	Started October 16, 1924		Started April 18, 1925	
	Number of Cover Slips Tested	Number of Tubes Showing Growth	Number of Cover Slips Tested	Number of Tubes Showing Growth
½ Hour	5	5	5	5
1 "	5	5	5	5
5 Hours	5	5	5	5
12 "	5	5	5	5
24 "	5	5	5	5
2 Days	5	5	5	5
3 "	5	5	5	5
4 "	5	5	5	5
5 "	5	5	5	5
6 "	5	5	5	5
7 "	5	5	5	5
8 "	5	5	5	5
10 "	5	5	5	5
12 "	5	5	5	5
15 "	5	5	5	5
18 "	5	5	5	5
20 "	5	5	5	5
25 "	5	5	5	5
30 "	5	5	5	5
40 "	5	5	5	5
50 "	5	4	5	5
60 "	5	5	5	5
70 "	5	5	5	5
80 "	..	..	5	5
82 "	10	4	..	..
85 "	..	..	5	5
90 "	..	..	10	1
95 "	10	1	10	6
100 "	..	..	10	4
105 "	..	..	10	3
106 "	10	0	..	..
110 "	..	..	10	1
115 "	..	..	10	1
120 "	..	..	10	2
127 "	..	..	10	4
133 "	69	0	..	..
140 "	..	..	10	1
145 "	..	..	10	0

These results show that the eye spot spores are very resistant to drying. The conditions of constant atmospheric dryness in the laboratory are probably more adverse to the fungus spores than the conditions which exist in cane fields, where occasional showers and a fairly high humidity exist. There is no question, therefore, but that the eye spot spores can survive in large numbers through the summer from one eye spot season to another.

Relation of Temperatures to the Growth of the Eye Spot Fungus

*A Review of a Paper by F. F. Halma and H. S. Fawcett**

Eye spot is generally considered a cold weather disease. There has been a feeling, however, that the relation of cold weather to the disease is not so much due to more favorable growth of the eye spot fungus at lower temperatures as to



Graph showing the growth of *Helminthosporium sacchari* at different temperatures with time.

* Phytopathology, Vol. 15, No. 8, p. 463, August, 1925.

the presence of moisture for long periods on the cane leaves, from dews, or rains in the colder months, and the lessened hours of sunlight during the winter months when cold weather occurs.

Apparatus and methods have been developed by Dr. H. S. Fawcett, of the University of California, to accurately compare the activities of fungi and other micro-organisms at different fixed temperatures. In order to save the time and expense of duplication of such apparatus, Dr. Fawcett was asked if he would test out the eye spot fungus at different temperatures with his apparatus in California, which he kindly consented to do. Cultures of the eye spot fungus, *Helminthosporium (Cercospora) sacchari* Butl. were, therefore, sent to Dr. Fawcett, and in the publication mentioned above he and Mr. Halma, his assistant, have recorded these results.

Growth Versus Temperature Experiments

The growth of the fungus was determined on standard nutrient agar, pH 6.8, in glass Petri culture dishes at various temperatures, as noted in Table I. The best average growth from ten such cultures at each temperature determined the optimum for the growth of this fungus.

The accompanying illustration shows the rate of growth of the eye spot fungus at different temperatures with advancing age.

From the illustration it can be seen that at 96.8° F. the fungus was at an entire standstill with practically no growth; the authors showed that the fungus was not killed at this temperature but growth merely stopped. Growth at 89.6° F., was very slow. Growth was most rapid at 84.2° F., but over a period of ten days growth at 68° and 74.3° F. was more extensive. Growth was considerably retarded at temperatures at 61.9° and 56.3° F. This is also shown in the results of the tests recorded in Table I.

TABLE I

Growth of *Helminthosporium sacchari* on Standard Nutrient Agar at Different Temperatures

Days	Temperature in Degrees Fahrenheit							
	56.3	61.9	68.0	74.3	78.8	96.8	89.6	96.8
1	5.1*	4.6	4.8	6.5	7.4	8.6	6.9	5.2
	0.2	0.2	0.2	0.3	0.4	0.6	0.4	0.2
2	7.6	8.6	10.1	12.7	15.4	18.2	12.1	7.2
	0.5	0.6	0.9	1.2	1.9	2.6	1.1	0.4
3	10.1	11.8	15.2	19.1	25.1	29.7	16.0	Growth ceased
	0.8	1.1	1.8	2.8	4.9	6.9	2.0	
4	12.1	15.2	19.2	26.1	32.6	39.2	18.8	
	1.1	1.8	2.9	5.3	8.3	12.1	2.8	
5	14.0	17.5	23.7	33.6	40.1	43.8	21.9	
	1.5	2.4	4.4	8.9	12.6	15.1	3.8	
6	15.7	21.0	29.2	37.8	42.8	44.5	24.6	
	1.9	3.5	6.7	11.2	14.4	15.5	4.8	
7	17.3	23.6	34.6	41.9	43.7	Growth ceased	28.9	
	2.3	4.4	9.4	13.8	14.9		6.5	
8	19.1	26.9	38.2	44.3	44.0		32.3	
	2.8	5.7	11.5	15.3	15.2		8.1	
9	21.1	30.1	41.1	46.3	Growth ceased		33.8	
	3.5	7.1	13.2	16.8			9.0	
10	23.1	32.6	44.2	Growth ceased			34.7	
	4.2	8.3	15.3				9.4	
11	24.5	34.6	46.4				36.3	
	4.7	9.4	16.9				10.3	
12	25.9	36.9	Growth ceased				36.5	
	5.3	10.7					10.4	

* Upper number = diameter of mycelium in mm.; lower number — area of mycelium in cm^2.

The data obtained on solid nutrient culture media were checked by weighing the fungus mycelium grown in liquid culture media at the same temperatures. The results of such tests in bouillon cultures are shown in Table II:

TABLE II

Temperature F. °	Average Weight of Air-Dried Mycelium in mg.	pH of Bouillon at End of 10th Day
56.3	51.0	6.9
61.9	75.0	7.3
68.0	126.0	8.0
74.3	132.5	8.2
78.8	157.0	8.2
96.8	136.5	8.2
89.6	53.5	7.0
96.8	10.0	6.9

The results of these weighings of mycelium grown in nutrient bouillon at the different temperatures are very similar to the results obtained on the solid culture media. In passing, Halma and Fawcett noted that the reaction of the bouillon became decidedly alkaline where vigorous fungus growth took place.

Discussion

When one considers temperatures at or near the sea level in the Hawaiian Islands one is led to the conclusion that ordinary winter temperatures, but not necessarily the extreme minimum temperatures, are more favorable for growth of the eye spot fungus than the summer temperatures. In Honolulu, the mean November temperature is 74.7°; December, 72.8°; January, 70.7°; February, 71.1°; and March 71.3°. These are the temperatures at which the eye spot fungus makes the most extensive growth.

The extreme minimum temperatures in the winter months have been: November, 59°; December, 55°; January, 54°; February, 52°, and March, 53°. These figures are taken from the records of the Honolulu office of the Federal Weather Bureau, U. S. Department of Agriculture, which have been compiled over a period of thirty-four years. These low temperatures only occur rarely and the fungus growth, although retarded at such temperatures, is not inhibited entirely.

On the other hand, mean summer temperatures run as follows: May, 74.8°; June, 76.4°; July, 77.4°; August, 78.2°; September, 78.0°, and October, 76.9°. The extreme maximum temperatures in the summer months are: May, 87°; June, 88°; July, 88°; August, 88°; September, 88°, and October, 90°. These figures are those of air temperatures at a considerable elevation above the ground and in the shade.

In cane fields, conditions are much more favorable for high temperatures than the conditions under which the above temperature figures were obtained. Our recording thermometers in direct sunlight frequently register 20° higher than an identical instrument in the shade, over a period of 6 to 8 hours each day. Where a recording thermometer will register 86° and 88° in the shade, an identical instrument in the direct sunlight near by will often register 108° or 110° F.

Moreover, it has been shown by investigators (Seeley) that green leaves in direct sunlight exceed atmospheric temperatures by as much as 20° or even 36°. Therefore, in summer months, in view of the results by Halma and Fawcett, with periods of 8 to 10 hours of direct sunlight the leaf temperatures would seem to be sufficiently high to inhibit eye spot growth entirely.

In winter months, direct sunlight is for much shorter periods and is also frequently obscured by clouds so that the direct effect of winter temperatures, regardless of the indirect effects of such temperatures in relation to moisture and rain, is more favorable for the development of the eye spot fungus than the summer temperatures.

In the absence of direct sunlight, leaves of plants quickly become colder than the air. In the winter months with longer hours of darkness, this difference may amount to 9° or 10° F. (Seeley), that is, cane leaves may be 9° to 10° cooler than the surrounding atmosphere. This, of course, brings about a condensation of the atmospheric moisture and results in long hours of dew on the leaves in the winter months of lower temperatures and shorter periods of direct sunlight. The indirect effects of winter temperatures, as well as the direct effect, are therefore much more favorable for eye spot development than the summer temperatures.

The knowledge of the temperature relationship to growth of the eye spot fungus will be available in other ways and will be referred to at other times. We feel very appreciative of the work of Mr. Halma and Dr. Fawcett in taking up this phase of our eye spot problem.

Summary

(1) Halma and Fawcett have shown that the eye spot fungus grows most rapidly at about 84° F. Growth is slower but continued longer at 68° and 74° F. At temperatures as low as 56° or 62° F. growth occurs but very slowly. At very high temperatures, also, growth is retarded; at 89° growth occurs but is very slow. At 96° F. the eye spot fungus makes no growth whatever.

(2) Although at sea level in the Hawaiian Islands the extreme minimum temperatures in winter are unfavorable for growth of the eye spot fungus, the mean temperatures in the winter months are very favorable. The extreme minimum temperatures occur in a very small percentage of the total hours in the winter months.

(3) Although the atmospheric temperatures in the summer months are not unfavorable to growth of the eye spot fungus, leaf temperatures in direct sunlight are 20° to 36° higher than atmospheric temperatures. Since growth of the fungus is more concerned with leaf temperatures than atmospheric temperatures, this point is of importance. Growth of the eye spot fungus is entirely inhibited at 96° F., according to Halma and Fawcett, and during a large percentage of the total hours in the summer months leaf temperatures of 96° F., or higher, occur.

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(H. A. L.)

Progress Report of Experiments with Fungicidal Dusts Against Eye Spot

By H. Atherton Lee and J. P. Martin

Although natural control by resistant cane varieties is the ultimate solution to prevent eye spot losses, there is a period of at least two or three years, or possibly ten years, before a satisfactory variety can be obtained and the H 109 areas with eye spot replanted to such a new variety. In this interim artificial methods for preventing eye spot must be employed, and by analogy with fungous diseases of other crops the use of fungicides is the measure which has most promise of success. Dust fungicides can be applied to cane fields with dusting machines at a reasonable cost, as we have shown (*The Hawaiian Planters' Record* for October, 1925; Vol. XXIV, No. 4, p. 377). Last winter, in cooperation with the Army Air Service, and in particular the personnel of Wheeler Field, experiments were tried with airplane dusting. Lieutenant O'Connell, of the Air Service, demonstrated that there was no obstacle to efficiently placing dusts on the cane fields in any situation. The experiments were carried on at the Oahu Sugar Company.

Coincident with these tests in methods of applying the dust, plot tests to determine the effect of various fungicides have been carried on. In the experiments six dust fungicides were tried out, the treatment with each fungicide having eight replications. The experiments were carried on in Field Mokuleia A-B of the Waialua Agricultural Company, where ample sources for eye spot infection were present.

The effect of the fungicides on the growth of the cane was observed by growth measurements and the increase or decrease of eye spot infection was observed by eye spot counts. For each plot ten stalks were used for growth measurements, or eighty per treatment. Eye spot counts were made on twenty stalks for each plot or 160 stalks per treatment.

The dusts were applied at two-week intervals commencing October 24, 1925, and closing February 25, 1926, there being nine applications in all for each treatment during the period of the experiment.

Of the six fungicidal dusts in the experiments, only one reduced eye spot. The results with this dust and two others are shown in the curves from the eye spot counts in Fig 1.

The curves in Fig. 1 show that eye spot started to increase on December 3 and reached the peak of infection on January 28. During this upward curve of eye spot infection the leaf counts showed the sulphur-treated plots with less disease fairly consistently. At the peak of infection, which is the critical time to reduce loss from top rot following eye spot, the amount of eye spot in the sulphur-treated plots was reduced 27 per cent as compared with the untreated plots. This reduction in eye spot was visible to the eye as well as by the eye spot counts. In the previous winter, 1924-1925, the sulphur-treated plots also showed less eye

spot visible than the control plots; the reduction was not complete prevention but must, nevertheless, have prevented a great deal of top rot.

There was no visible injury to the cane from the dust in the sulphur-treated plots as compared with the untreated plots. The growth measurements of the cane in all the three treatments and controls are shown in Fig. 2.

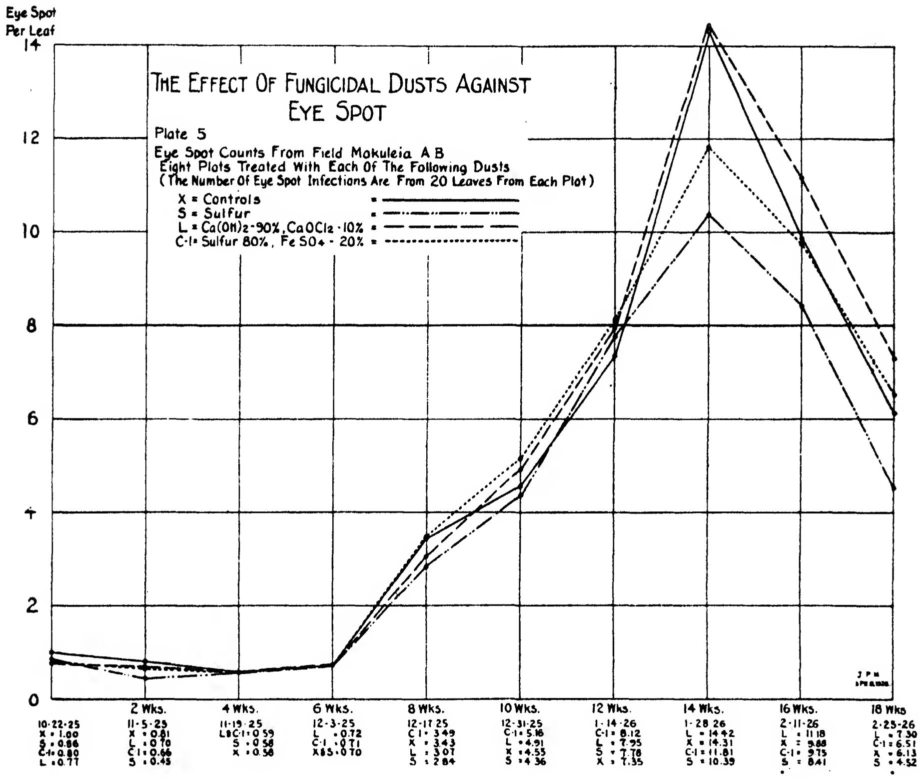


Fig. 1. Curves plotted from eye spot leaf counts in experiments testing fungicidal dusts. Each point on the curve is taken from 20 leaf counts per plot and there are 8 plots to each treatment, making 160 leaf counts per treatment. Note the beginning of the eye spot curve on December 3 and the peak of infection on January 28. At the peak of infection the sulphur-dusted plots showed 27 per cent less eye spot than the undusted controls.

In the foregoing tests the sulphur-dusted plots were at a disadvantage as compared to field dusting for the reason that each dusted plot was surrounded on all sides with heavily infected cane in the control plots or unsuccessfully dusted plots of the other fungicides. These other plots therefore afforded constant sources for infection of the dusted plots, which would be reduced by 27 per cent or more, if the dust was applied on a field scale. On a field scale dusting with sulphur would therefore be expected to be more successful than in the plot experiments just recorded.

Experiments with sulphur as a dust fungicide against wheat rust were carried on last year by the experiment stations in Manitoba, Minnesota and New York. The experiments were consistent in each place and showed a profitable

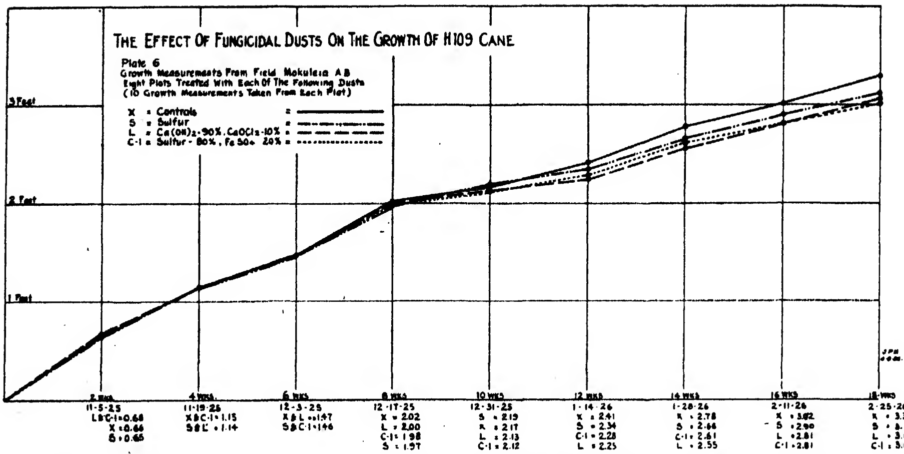


Fig. 2. Showing curves plotted from growth measurements of each treatment in the fungicidal dust test. There were 10 stalks measured per plot and 8 plots per treatment, making 80 growth measurements for each class of treatment. There seems to be little or no effect on the growth of the cane resulting from the fungicides.

reduction of rust by the treatments. In the experiment it was also shown that by increasing the dust applications from two-week intervals to only one-week intervals the reduction in rust was almost doubled.

In the coming winter the experiments will include a series of plots in which the intervals between sulphur treatments will be decreased. Adding other constituents to the sulphur dust is also being tried.

To the present time we have had no success against eye spot with the common dust fungicides containing copper, such as Bordeaux dust. The results with sulphur, although not completely effective, are sufficiently good to encourage us to try to improve upon it.

Appreciation is expressed to the Waialua Agricultural Company for their cooperation in carrying on these tests.

The Control of Eye Spot Through Resistant Varieties

By J. P. Martin and H. K. Stender

Previous to the winter months of 1924-1925 eye spot disease was considered more or less a minor cane disease although at times epidemics have developed in certain localities on susceptible varieties causing appreciable losses. With the recent increased planting of H 109 cane, especially in eye spot areas, the disease began to manifest itself and become a major cane disease.

The only final control of the disease will be effected by planting resistant varieties in those areas now affected with the disease. By removing the susceptible host the disease will naturally be reduced, thus offering greater protection to

entire plantations concerned. Some of the standard varieties such as Yellow Caledonia, Badila, Uba and Striped Mexican possess qualities of high resistance to the eye spot disease. These varieties could be planted in those areas of H 109 now badly affected with the disease but a sacrifice in sugar production would result because the sugar yield of these standard resistant varieties is considerably lower than that of H 109.

Showing the resistance to eye spot disease offered by Waialua seedling No. 1 as compared with H 109. Note that the disease has not only greatly retarded the growth of H 109 as compared with the seedling, but has killed a great portion of the H 109.

If crosses in breeding work are made with standard eye spot-resistant canes and H 109 cane, a few seedlings of the progeny of this combination should possess both qualities of eye spot resistance and high sugar production.

The following is a brief account of seedlings obtained by crossing H 109 cane with a very eye spot-resistant standard variety and also the potential possibilities of selecting a cane that will be commercially resistant to the disease and at the same time compete with H 109.

During the early part of 1924 this Station sent to Waialua Agricultural Company, Ltd., 400 young potted seedlings of that year's propagation. The parentage of these seedlings was three-quarters H 109 and one-quarter Striped Mexican.

Field Ranch 2B where the above mentioned seedlings were planted was quite severely affected with eye spot during the eye spot season of 1924-1925. Since the parentage of these seedlings gave promise of producing resistant canes, it was decided to make a detailed inspection of all seedlings and select only those possessing high degrees of resistance to the disease as well as good agricultural qualities. This selection was made the first part of March, 1925, at the peak of the eye spot

season. In all, nine seedlings were selected and carefully labeled for further propagation. These nine seedlings were selected primarily because they had developed so little eye spot in a very heavily infected area, and secondarily because they possessed good agricultural qualities. Y. Kutsunai and R. Conant, of this Station, made the selection on the agricultural basis while the senior author of this paper selected them because of their resistance to the eye spot disease.

The nine seedlings selected were numbered Waialua 1 to 9, inclusive, and were left to grow until November, 1925. At this date all available cuttings from each stool were carefully taken and planted in Field Gay 8A, which is located in another bad eye spot area. Equal amounts of H 109 cane were planted between the Waialua seedlings so a comparison could be made at all times.

The effect of eye spot on H 109 cane in the foreground as compared with Waialua seedling No. 6. Much of the H 109 cane has been killed from the disease, while Waialua 6 showed only a few minute infections which never developed large lesions.

All seedlings as well as H 109 germinated readily and numerous eye spot infections began to appear on H 109 and in lesser numbers on the Waialua seedlings. A few of these seedlings immediately began to show extreme resistance to the eye spot disease and maintained this resistance throughout the eye spot season. The seedlings in order of their resistance may be listed as follows: 1, 9, 6, 3, 8, 4, 5 and 7. Since eye spot became so severe in this area the growth of the young H 109 cane was greatly reduced and a fair comparison of growth between the Waialua seedlings and H 109 could not be made. All seedlings with the exception of Waialua 3, 5 and 7 were well ahead of H 109 in growth under the existing conditions. Much of the H 109 cane was killed by February 1, 1926, because of

the severe attack of eye spot. The resistance to the disease is well brought out in the accompanying photographs of two of these seedlings when compared with H 109. These photographs were taken at the height of the eye spot season by Twigg Smith.

Because of the promising possibilities of these seedlings further plantings from the best of these seedlings were carried out on July 20, 1926. All seedlings with the exception of Waialua 5 and 7 were planted to determine cane weights and juices in carload lots. To date nothing is known of the sugar content, ratooning qualities or other desirable qualities, but this experiment is well under way so that this information will be had at the earliest possible date.

In summarizing we can say that certain Waialua seedlings possess to a marked degree the desired eye spot resistance. These seedlings or others, if they prove satisfactory in other respects, may in the course of time be used to replace H 109 cane in certain areas which are at present badly affected with eye spot disease.

A Method of Testing Cane Varieties for Eye Spot Susceptibility and Resistance

By H. Atherton Lee, J. P. Martin and C. C. Barnum

It is appreciated by all, that natural control of insect pests or infectious diseases is the cheapest and most satisfactory preventive measure if entire exclusion of such troubles from the country has not been possible. In case of cane diseases the only effective natural control known at the present time is by the use of cane varieties resistant to such diseases. For eye spot prevention therefore, although attempts are being made for more immediate control, the ultimate preventive measures to be achieved, will be in the use of varieties resistant to eye spot and producing sugar yields as satisfactory as the present susceptible variety H 109. This is not as simple as may at first appear, for H 109, in addition to its high yields, is remarkably resistant to many forms of root injury and is tolerant to, and not readily infected with, mosaic disease.

In order to quickly recognize eye spot resistance or susceptibility in newly introduced varieties or new seedling varieties, a test has been developed which can be completed in ten days' time and which is also more accurate than most field observations; this method is called the eye spot index test.

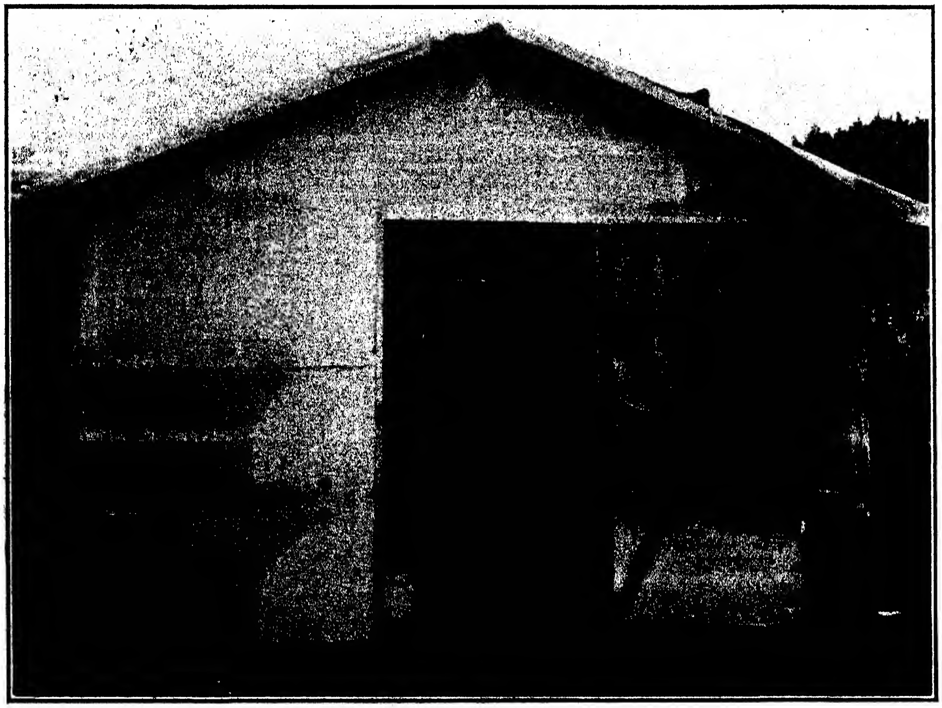
Methods of Eye Spot Index Test

The method in principle consists in producing eye spot on the varieties to be tested by spraying the spores of the eye spot fungus on such varieties under conditions in which eye spot will develop. The amount of the resulting eye spot infection is compared with the eye spot infection on H 109 sprayed with the same spore infusion and exposed to the same conditions as the varieties under-

going the test. Usually the resistance or susceptibility of six varieties is determined in one test.

Collecting the Cane to be Tested

Ten stalks of a variety to be tested are cut in the field and the cut ends immediately immersed in fresh water. Usually, to get cane of approximately the same age, stalks are cut on which ten joints have formed. These stalks are transported to an eye spot cage where they are removed quickly from the water and placed in the sulphurous acid solution which has been developed by J. A. Verret



The eye spot moisture cage used in testing cane varieties for eye spot susceptibility and resistance. The sides and door are lined with burlap sacks. These were kept saturated at all times during the experiment. Note hygro-thermograph inside cage.

and his associates for holding cane tassels for breeding work. This solution consists of 1 part of sulphurous acid in 3,300 parts of water. During the gathering of the cane stalks it is essential to keep the leaves protected from the sun and wind, especially when the stalks are transported from any great distance.

Eye Spot Moisture Cage

The eye spot cage consists of a chamber with cloth sides, which can be kept wet, thus keeping the humidity in the cage high enough to maintain free moisture on the cane leaves. It is desirable to have the top of the cage covered with an opaque cloth such as burlap sacking, or a tarpaulin, in order to exclude the direct

rays of the sun from the cane leaves. This results in the cane leaves being slightly cooler than the atmosphere and in the condensation of moisture on the leaves rather than evaporation which occurs in direct sunlight. An illustration of the eye spot moisture cage is shown here.

Infusion of Eye Spot Spores

An infusion of the eye spot spores is next prepared in the following manner: The spores are taken from pure cultures of the eye spot fungus grown in Petri dishes on nutrient agar; the cultures are usually about ten days old and have been grown in total darkness. The infusion is made in tap water and a 3 mm. loop of the infusion is examined under the microscope, to be assured that the spores are present in sufficient quantity; it is desirable to have from 15 to 25 spores to such a drop. The same infusion is used for all varieties in a single test and the H 109 stalks used for comparison.

Hygro-thermograph in the Cage

The humidity of the eye spot cage is then raised to above 90°. A recording hygro-thermograph is maintained in the cage in order to be informed of the humidity and temperature conditions. The cane stalks and H 109 controls to be tested are then sprayed several times with the eye spot spore infusion, at three- to four-hour intervals. A rather large atomizer, called the Rose sprayer, is used for spraying the spores on the cane. Free moisture is maintained on the cane leaves for at least forty-eight hours following this inoculation in order to favor the germination of the spores and the penetration of the fungus hyphae into the leaf.

Methods of Taking Results

At the end of ten days, the eye spot lesions on the six youngest leaves of each of the ten stalks of each variety in the test are counted, measured and tabulated. The total lesions on variety A are compared with the total lesions on H 109, and so also for each of the other varieties in the test.

It is becoming more and more the trend in all biological reactions to endeavor to express results numerically or mathematically, since results so expressed are so much more accurate than by other means.

In the present tests, if we give H 109 susceptibility an empirical value of 1,000, then the number of eye spot infections on the ten stalks of variety A, is to the number of eye spot infections on the ten stalks of H 109 as X is to 1,000 and X will represent numerically the susceptibility of variety A; this may be expressed by the following equation:

$$\frac{\text{Eye spot infections on Variety A}}{\text{Eye spot infections on H 109}} = \frac{X}{1000}$$

The values obtained for X for the different varieties in the test are called the eye spot infection index numbers of such varieties.

Usually each variety is subjected three times to the above test. As an example of the above equation, ten stalks of the variety P. O. J. 36 after inoculation with eye spot spores, at the end of ten days in the eye spot cage, showed 157 eye spot infections as compared to 814 eye spot infections on identically treated H 109. The eye spot infection index for P. O. J. 36 would therefore be determined as follows:

$$\frac{\text{Eye spot infections on P. O. J. 36 (157)}}{\text{Eye spot infections on H 109 \quad (814)}} = \frac{X}{1000}$$

$$X = \text{eye spot infection index of P. O. J. } 36 = 192$$

However, many cane varieties although they become readily infected with eye spot, do not suffer from the disease, because the spots formed are small and the streaks or runners fail to develop. For this reason there are two types of resistance to eye spot; resistance to infection, and tolerance after infection. The foregoing method has been a measure of determining the susceptibility of a variety to infection; the following is a method of determining the tolerance of a variety after infection.

The tolerance index is obtained by measuring the length of all eye spot infections, plus the length of the streaks if they are produced; in other words the total lesions on ten stalks of the variety to be tested and comparing the total length obtained from such measurements, with the total length of lesions on ten stalks of H 109 under identical conditions.

Thus P. O. J. 36 in the test quoted above gave 157 eye spot lesions which totaled 1045 mm. in length. Ten stalks of H 109 under identical conditions yielded 814 lesions which totaled 4736 mm. The tolerance index would be determined as follows:

$$\frac{\text{Total length of eye spot lesions on P. O. J. 36 (1045)}}{\text{Total length of eye spot lesions on H 109 \quad (4736)}} = \frac{X}{1000}$$

$$X = \text{eye spot tolerance index} = 220$$

P. O. J. 36 thus, has an eye spot infection index of 192 and a tolerance index of 220.

Results of Eye Spot Index Tests

The following are some of the results obtained from eye spot index tests to date, as shown in the following table:

Variety	First Test Infection Index....	First Test Tolerance Index....	Second Test Infection Index....	Second Test Tolerance Index....	Third Test Infection Index....	Third Test Tolerance Index....	Averaged Results Infection Index....	Averaged Results Tolerance Index....
H 109	1000	1000	1000	1000	1000	1000	1000	1000
P. O. J. 36..............	192	220	183	211	55	88	181	211
P. O. J. 213.............	0	0	0	0	44	18	2	0.1
P. O. J. 234.............	0	0	8	4	0	0	3	1
P. O. J. 979.............	126	61	13	10	0	0	73	40
U. D. No. 1..............	582	526	511	374	209	161	531	453
Yellow Caledonia	174	59	....	....	....	....	174	59
H 109	1000	1000	1000	1000	....	....	1000	1000
H 8942	824	671	483	344	....	....	511	381
H 8965	391	418	280	333	....	....	289	342
Uba	195	80	20	15	....	....	34	14
H 109...................	1000	1000	1000	1000	1000	1000	1000	1000
H 8994	216	51	281	96	285	85	261	77
Makaweli 3	308	67	56	22	185	45	183	45
Wailuku 8	1730	1204	1128	818	1878	1488	1575	1203
Wailuku 11	648	413	547	595	690	550	532	523
Wailuku 29	934	787	856	1072	974	911	921	890
H 109	1000	1000	....	....	....	....	1000	1000
H 8906	1132	921	....	....	....	....	1132	921
H 8952	360	82	....	....	....	....	360	82
H 8961	343	57	....	....	....	....	343	57
H 8988	775	444	....	....	....	....	775	444
H 89102	915	574	....	....	....	....	915	574
H 8993	275	47	....	....	....	....	275	47

The above table shows fairly consistent results for an extremely complex biological reaction involving factors such as climatic conditions where the cane was growing, condition of the cane as to vigor, viability of the fungus spores and other variables. In the case of two varieties the results have been thrown out, since they were not consistent and could not be depended upon.

From the results in the above table it may be said that P. O. J. 213, 234 and 979, Yellow Caledonia, Uba, H 8994, Makaweli 3, H 8961 and H 8993 are all commercially resistant to eye spot. These results illustrate the feasibility of obtaining varieties of strong resistance to the disease. Many such canes will be definitely inferior to H 109, but the yielding power of all such varieties should be carefully studied.

There are several varieties in the list which are susceptible, but much less so than H 109 and if planted in large blocks, away from heavy sources of infection would not suffer severely from eye spot. H 8965 and P. O. J. 36 are the most promising of such varieties.

Nevertheless there is no question but that a cane will ultimately be secured, satisfactory in yield and resistant to eye spot. The eye spot index tests described

here will permit immediate recognition of eye spot resistance in such a variety when it occurs.

Summary

1. By collecting stalks of different cane varieties under comparable conditions and spraying them with spores of the eye spot fungus, it is possible to make a comparison of the susceptibility of such varieties with the susceptibility of H 109.

2. By giving an empirical value of 1000 to H 109 to represent its susceptibility it is possible to express numerically the susceptibility of other varieties in such tests.

3. The new varieties tested to date which show high degrees of resistance to eye spot are P. O. J. 213, 234, 979, Makaweli 3, H 8994, H 8993, H 8961 and H 8952. Such varieties as H 8965 and P. O. J. 36 are more susceptible but could be grown in fields with a history of eye spot with minor injuries if planted in large enough areas to be away from heavy sources of infection.

4. Of the standard canes being grown at present, which have been tested, Yellow Caledonia and Uba have shown the highest resistance to eye spot.

Credit should be mentioned for assistance in carrying on these tests to Messrs. Royden Bryan and Z. A. Romero.

Galls on Sugar Cane in Hawaii

By H. L. Lyon

During the past two years, considerable interest has been aroused at the Experiment Station by the appearance of overgrowths or galls on the stalks of many canes growing at the Makiki Plots in Honolulu. These galls have been the most numerous and attained the greatest size and complexity in certain seedling canes which are descendants of Uba, but they have also occurred at the same time on several other canes in the pedigrees of which Uba does not appear. We have made no extensive or intensive search for these galls on canes in plantation fields, but we have been able to find at least a few of them in every block of Uba seedlings of any size which we have examined. They have also been found in recent months on H 109 and other canes in plantation fields on Hawaii, Oahu and Kauai.

The appearance of external galls or tumors on cane stems is, by no means, a new phenomenon to us here in Hawaii and their occurrence on canes in Java was recorded many years ago. On all previous occasions (*except one*) when such galls were noted in Hawaii, they were few in number on the individual sticks and the affected sticks were widely separated in the fields. The cases have always been sporadic or transitory, or confined to a single variety of cane. In view of

these facts, we were forced to view them as freaks such as may be found on occasion in any variety of plant and due to temporary derangement of the vital mechanism which controls the growth of the plant.

In the present instance, however, galls have been found in varying numbers on many varieties of cane within a restricted area. In several varieties, they have appeared continuously and in great numbers on every stick; and, in a few varieties, their development has proceeded to such an extreme as to render the canes quite worthless for commercial purposes. Such circumstances call for a radical revision of our former conclusions regarding the causation of these galls, for the evidence now at hand would seem to indicate that we are dealing with a malady caused by some factor quite foreign to the vital mechanism of the cane plant since it operates simultaneously on many individuals of many different varieties.

Nature and Distribution of Galls

As a rule, these galls develop as superfluous appendages on nodes and internodes that are apparently normal in all other respects; shave off the galls and you have left normal-appearing canes. In some aggravated cases, however, the development of the external galls is accompanied by more or less distortion, displacement and atrophy within the tissues of the members from which they spring and a conspicuous monstrosity is the result.

In the majority of affected canes, nodes and internodes of normal shape and structure are differentiated in proper sequence from the growing point of the stem. While their tissues are still near-embryonic, i. e., before they have become completely transformed into permanent tissues, groups of cells at and near the surface break from the course of development required of them by their position in the stem and, multiplying rapidly, produce an excess of tissue which protrudes beyond the normal surface of the stem as an overgrowth or gall. When the rudiments of the galls are first discernable with a low-power hand lens (× 10), they look like delicate water blisters, some standing singly and others running together in variously shaped groups. These blisters soon grow into galls of the most irregular and diverse shapes. The forms assumed include threads, ridges, plates and nodular masses with galls of each type distorted in every possible manner. The tissue in the young galls is all embryonic or meristematic and consequently very delicate. It would shrivel up very quickly if exposed to the air, but since the galls begin their development on very young nodes and internodes, they are protected for a long time by the overlying leaf sheaths. They are, therefore, required to pass through their early development in very restricted quarters and, being more or less plastic throughout this period, their shape is determined, to a considerable degree, by the leaf sheaths which closely cover them. As a result, the young galls are always more or less flattened against the stem. It is not uncommon to find a large, flat gall connected to the cane stalk by a very small neck of tissue which indicates the size of the initial protuberance.

Galls may develop at any point on a node or internode not occupied by a leaf or bud, but they spring most frequently from the root band and stem node; regions in which the tissues retain their meristematic properties longer than do

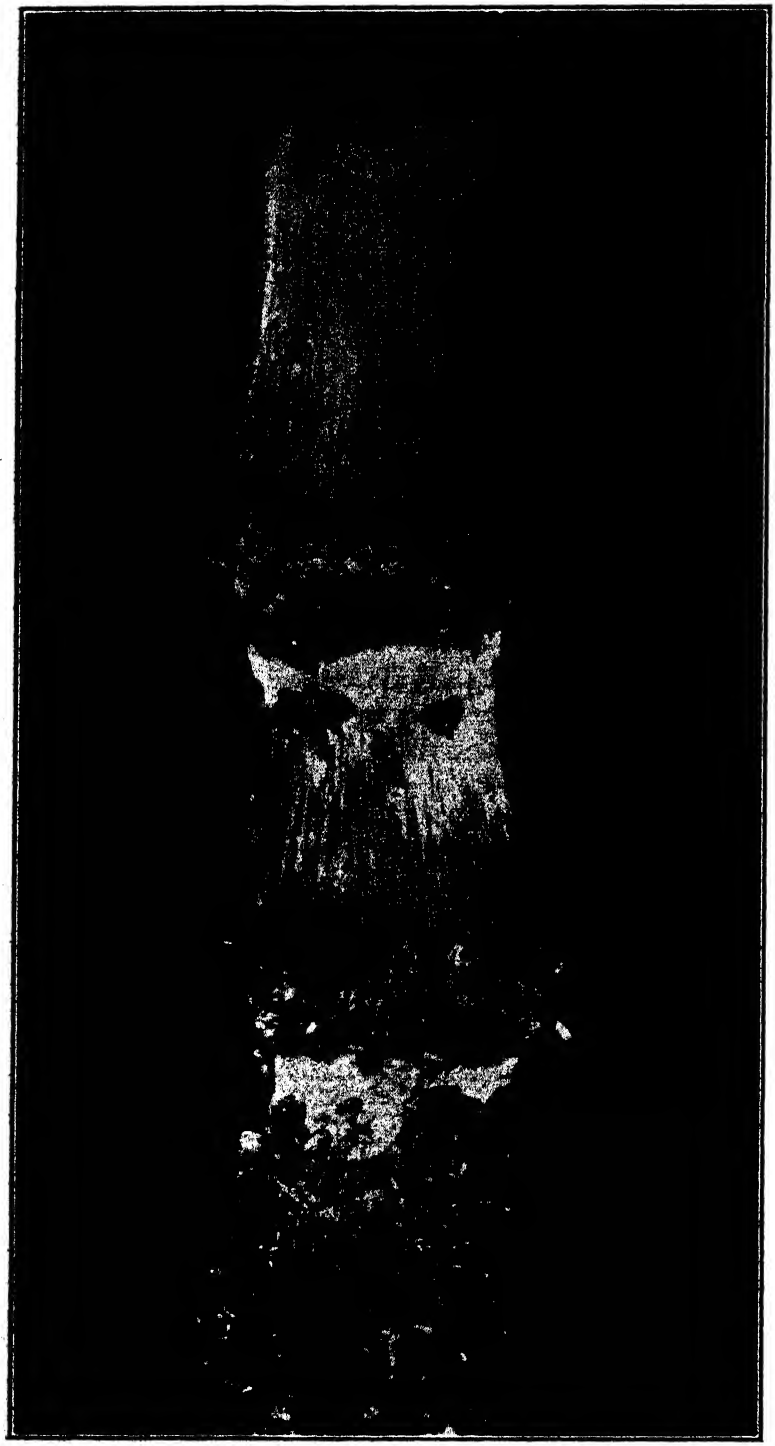


Fig. 1. A stick of U. D. 47 showing an extreme case of gall production. The lowermost internode shown in the picture is covered with galls while the other two internodes are badly deformed.

the tissues of the internode. In severely affected canes, it frequently happens that all of the superficial tissue of a root band and the adjoining stem node becomes involved in the production of galls. In such canes, galls may also appear on the outer surface of the leaf sheath and on the outer scales of the bud.

Some galls attain a large size without undergoing any appreciable differentiation, but many of them show a tendency at an early stage in their development to elaborate leaf tissue. This is most often evidenced by the production of thin plates of tissue in which strands of vascular tissue may be differentiated with each strand surrounded by mesophyll cells.

An entire gall may become transformed into a folioid structure or it may simply develop one or more folioid appendages. In some canes in which gall production has become chronic, the galls on the root bands and stem nodes regularly become very large and as regularly differentiate into adventitious buds which are exactly comparable to normal buds and, like them, may develop into leaf-bearing shoots. Adventitious buds are very rarely differentiated out of galls springing from an internode. When a lateral stem gall gives rise to folioid structures without first differentiating a bud or growing point, these structures never attain any considerable size and do not approach in any degree the complexity of a leaf. They are, as a rule, very thin and frail, quite devoid of any semblance of a midrib and, in fact, only comparable in structure to the auricle of a leaf.

The ultimate size and complexity which a gall may attain seems to be determined more or less definitely by the stage of development which it reaches before it is exposed to the air and light by the falling away of the overlying leaf bases. A gall is an exogenous outgrowth and, unless it organizes a bud and thus protects a growing point with scale leaves, its meristematic tissue is fully exposed to the air when the leaf sheaths fall away. Under ordinary weather conditions in Honolulu, such tender gall tissue, when exposed to the air, either passes over quickly into permanent tissue or dries up and dies. Such drying is not confined to the meristematic tissue only, for many of the folioid structures also dry up and the sticks bearing them look as though they were covered with dry, brown scabs. Buds which have been organized out of gall tissue and exposed by the falling away of the leaves may continue their growth and, under favorable conditions, develop into normal shoots.

As previously noted, the entire root band may be involved in the production of galls and this leads to the obliteration of all of the primordia of adventitious roots normally laid down in this region. It seems that the factor inducing gall production tends, at the same time, to lessen or suppress the normal tendency in the stem to produce adventitious roots. At any rate, we have had difficulty in getting badly galled cuttings to produce a sufficient number of roots to supply the needs of the aerial shoots which spring from them.

It was early noted that, in canes severely affected by the malady, incipient galls could be easily detected on the tender tissues within half an inch of the growing point of the stem. This suggested the question: what would be the result if the growing point of the stem were taken with a spasm of gall production? Would it not be a malgrowth such as we have previously known and described

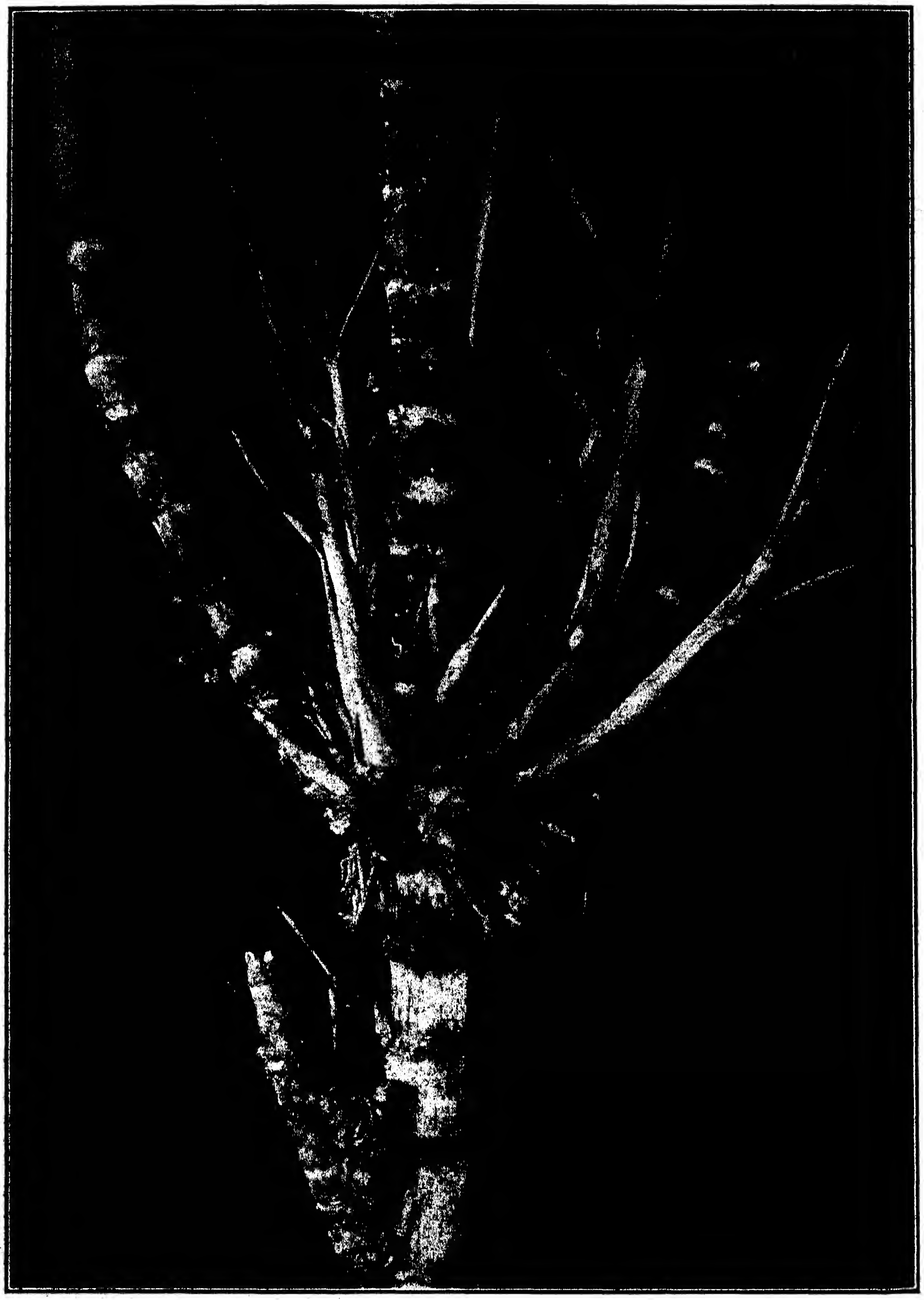


Fig. 2. A stick of U. D. 47 heavily infested with galls, many of which have given rise to adventitious buds and some of these have developed into leafy shoots.

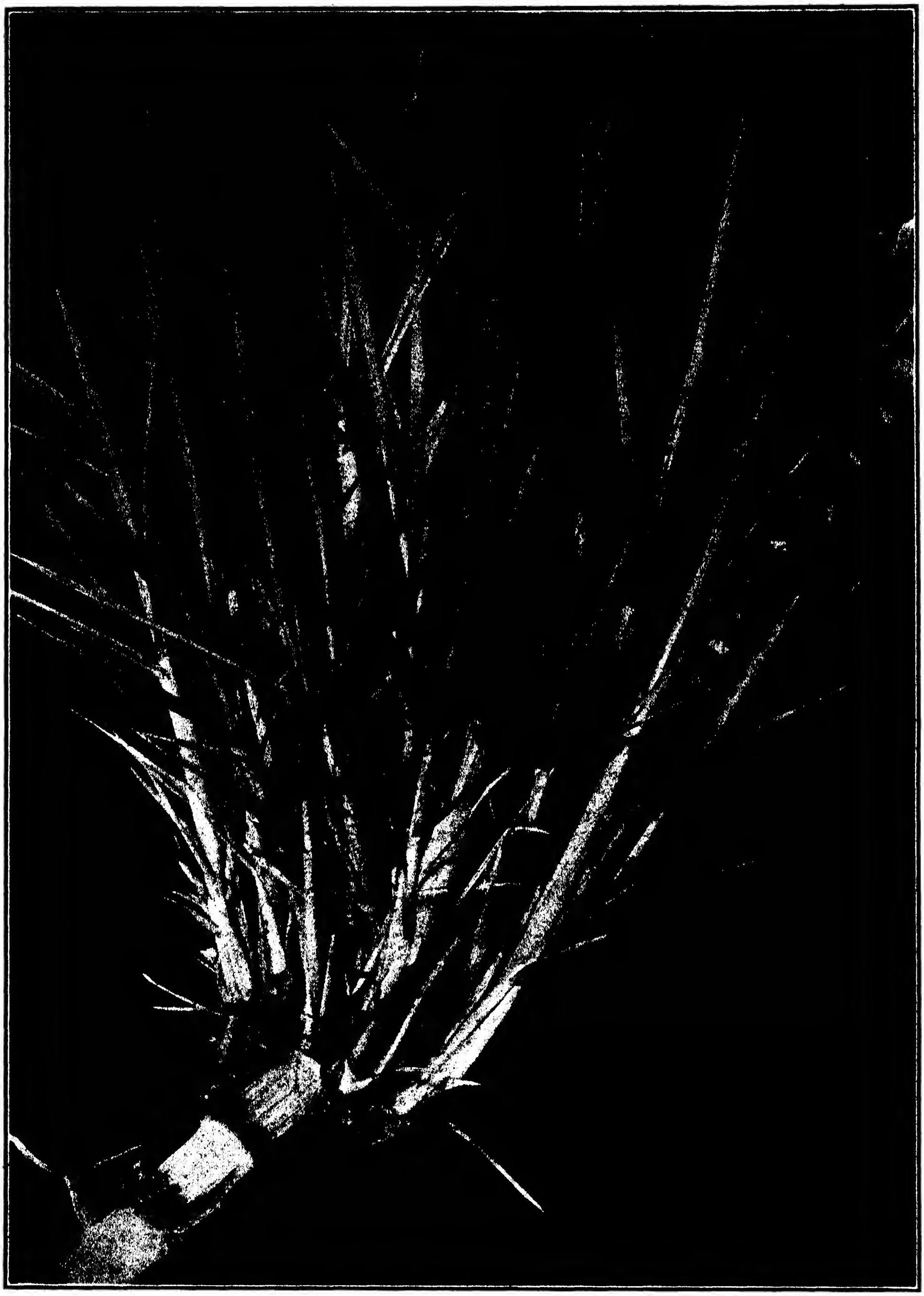


Fig. 3. A badly galled stick of U. D. 47 bearing a great cluster of closely set shoots which have developed from adventitious buds.

as bunch-top? To answer these questions, we set about to dissect out the growing points of a large number of sticks, choosing such as were severely affected with galls on their exposed parts. Our search resulted in bringing to light several cases of bunch-top in initial stages of development. This not only tied up the malgrowths known as bunch-top with the malady now under discussion, but gave us information regarding the development of these malgrowths which we had previously sought, but never been able to obtain.

When many of the badly galled canes at the Station were cut in March, 1926, a casual survey was made for bunch-top and many cases in advanced stages of development were detected. Sufficient evidence was obtained to fully demonstrate that bunch-top is a gall of the same nature as the lateral stem galls, but much more elaborate because more embryonic material is involved to start with and conditions are more favorable for its continued development. Being terminal, it enlarges into the space normally occupied by the spindle of leaves and so its development is not at any time checked for want of room.

A great variety of these terminal galls or bunch-tops have been found and examined and, no doubt, many more forms will be met with in the future. In general, they behave as do the lateral stem galls in that they produce leaf-like structures and buds. The folioid structures sometimes reach a length approximating that of the normal leaves and they sometimes show almost or quite as complete differentiation into tissues; more often, however, they are quite devoid of a midrib or any semblance thereof. When terminal galls differentiate buds, these may at once grow into shoots bearing normal leaves.

Specimens of bunch-top thus far met with range from a bundle of strap-shaped folioids to a bundle of closely set shoots. Between these two extremes, we have mixtures of strap-shaped folioids and leaf-bearing shoots in various proportions. It is not uncommon for a bunch-top to produce a terminal bud which grows up beyond the gall as a normal-appearing shoot or stick. In rare cases, two or three buds may develop and grow side by side into shoots. The result is a bifid or trifid stick with a distorted section at the point of branching, this section being marked with several or many small, oblique and otherwise abnormal leaf scars. See Figs. 6 and 7.

Sticks showing no galls whatsoever at any other point may develop a bunch-top and we have found cases of bunch-top in one variety, U. B. 3, Fig. 7, of which no sticks have ever been found bearing any other type of gall.

Cane Galls at the Experiment Station

Of the many canes growing on the Makiki Plots in Honolulu, galls have been found during the past ten months on the seventy-four varieties listed hereunder:

U D series, Nos. 13, 14, 20, 21, 22, 25, 28, 29, 30, 32, 33, 35, 39, 40, 47, 56, 60, 67, 68, 70, 75, 80, 88, 92, 99, 106;

25 Q series, Nos. 12, 15, 26, 77, 88, 104, 105, 110, 112, 116, 117, 137, 165, 206, 222;

24 H series, Nos. 16, 40, 59, 65, 71, 81, 93, 100, 107, 120;

25 C series, Nos. 5, 9, 15;

Fig. 4. Bunch top. This specimen was figured and described in the *Record* in 1910. Vol. II, No. 6, pp. 341-342.

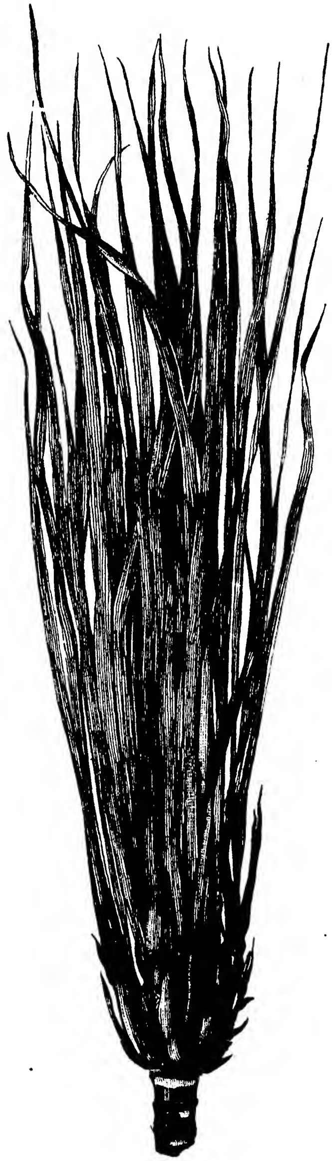


Fig. 5. Bunch top. This same cut was used in our paper on "Sereh" published in 1921. Bull. of the Exp. Sta., H. S. P. A., Bot. Series, Vol. III, p. 29, 1921.

1918 O. P. 328, 1919 O. P. 561, 1919 O. P. 803, 1919 O. P. 822, 1920 O. P. 296, 1920 O. P. Special 2, 1920 O. P. 593, 1924 O. P. 47, H 109 x D 1135, H 109, H 9921, Puaole, Ewa 800, Ewa 801, Wailuku 1, Wailuku 9, Makaweli 1. Honokaa U H 3, 26 Q 235, U B 3.

Uba is a parent or grandparent of forty-four of the canes enumerated above. The other thirty varieties are derived exclusively from big-stick canes: Puaole is a native Hawaiian cane and the rest are seedlings of Lahaina, Striped Mexican, Yellow Caledonia and D 1135.

Fig. 6. Bunch top in U. D. 67. Except for their rather narrow sheaths, these leaves are normal, each having a well developed midrib.

Fig. 7. Bunch top in U. B. 3. The number of folioids elaborated may be noted from the leaf scars. In the case on the left, two buds developed as growing points, producing a bifurcated stick, while a single bud grew out from the bunch top on the right.

These canes do not, by any means, suffer equal injury under the attacks of this malady. In many of the seventy-four varieties listed above, galls have been found on a very few sticks only and in the majority of these cases, the galls are small and so widely scattered as to render detection difficult, while the individual sticks bearing them are not appreciably affected.

In several of the varieties, however, gall production has become epidemic and chronic; galls appearing continuously and in great numbers on every stick. Up to the present time, U D 47 and U D 67 have been the most severely affected canes and these two varieties were eliminated from our cultures at the Makiki Plots in March, 1926.

Galls in varying numbers have been found on H 109 in eight separate plantings at the Station; two of these being plantings of selected progenies.

Galls on Imported Canes

In June, 1925, a proliferating gall was discovered on a stick of P. O. J. 2714 growing in the quarantine house at the Pathology Plot in Honolulu. The stool bearing this stick was promptly condemned by the pathologists and destroyed. A few weeks later, a similar gall appeared on a stick of P. O. J. 2725 growing in the same house and all of the canes then in the Quarantine House were destroyed as a precautionary measure.

Galls on Canes in Hawaii in Former Years

Small, nodular or folioid galls similar to those now appearing on our canes at the Experiment Station have been seen on sticks of the standard cane varieties in Hawaii at various times during the past twenty years. As previously stated in this article, these galls have, except in one case, always appeared singly or very few in number on isolated sticks and were consequently given very little consideration. The one exception was supplied by a seedling cane raised and propagated on Maui. In May, 1920, W. W. G. Moir sent from Maui to the Station, for examination, a stick of cane literally covered with nodular and folioid galls. E. L. Caum was sent over to Maui to examine this cane further in the field and to secure additional material for study. In a letter dated June 1, 1920, Mr. Caum wrote from Wailuku as follows: "It is a seedling of H 109, No. 44914 grown at Wailuku and planted in Field D, H. C. & S. Co. In the 15-foot row, there were thirty sticks, twenty-seven of which showed the wound-tissue in some degree." These sticks were badly infested with acari and we concluded at that time that the galls were induced by the mites. The particular seedling affected was discarded.

While working at Waipio substation in 1920, Messrs. Caum and Moir discovered a single stick of H 240 bearing large galls on two root bands. One of these galls had already developed several large buds. A photograph of this specimen is reproduced herewith as Fig. 8. The large bud-bearing gall was cut from the stick and planted at the Makiki Plots. It gave rise to a normal stool of cane which persisted until 1926, when it was dug out and destroyed. Galls were never noted on any of the sticks arising from this stool.

Fig. 8. Galls on H 240. The large gall on the right side of the middle node bearing several adventitious buds was planted and gave rise to a normal stool of cane.

Bunch-tops have also been found in Hawaiian cane fields at intervals during the past twenty years. They are always conspicuous objects in a cane field because of their large size and peculiar composition and consequently are more easily detected than are the lesser nodular and folioid galls which occur as lateral outgrowths on the stem.

During the spring of 1910, bunch-tops appeared in considerable numbers on several varieties of cane and on widely separated plantations. They attracted much attention and caused considerable apprehension as some observers were inclined to consider them malgrowths induced by sereh. After studying sereh in Java, we were able to say very definitely that bunch-top had no connection with this disease. It then appeared to represent a separate and unique problem in cane pathology. In 1921, we offered the conclusion that "Bunch-top is a malgrowth resulting through the abortion of an inflorescence or tassel. The growing point of the shoot reverts to vegetative growth after starting the development of an inflorescence, and a bunch-top is the result."

In the light of our present knowledge, we must withdraw this conclusion and place bunch-top in the category of a gall induced by extraneous forces.

Galls on Canes in Java

When we visited Java in 1911, we carried with us illustrations of bunch-top. These we submitted to Miss G. Wilbrink, pathologist at the East Java Experiment Station, and she informed us that nothing of the sort had, to the best of her knowledge, ever been seen on canes in Java. No specimens approximating bunch-top were to be found in the museum at the Experiment Station, but several well-preserved specimens showed lateral galls on the nodes, internodes and buds. Some of these galls had organized folioid outgrowths and others had given rise to adventitious buds. One specimen which particularly attracted our attention showed gall tissue arising throughout the entire extent of practically every root band with each mass of gall tissue giving rise to many adventitious buds. A photograph of this specimen is reproduced herewith as Fig. 9.

Miss Wilbrink called to our attention an article by Kamerling, which had been published in the *Archief* in 1900. In his paper, Kamerling describes and illustrates galls on cane which are in every way identical to those occurring on our canes here in Hawaii. Immediately following this paper will be found a translation of Kamerling's article prepared by W. van H. Duker.

When Miss Wilbrink visited Hawaii during April and May of the present year, she was shown canes bearing galls and she stated that the galls were of exactly the same nature as those which she had often observed on canes in Java.

After discussing this subject in all of its various phases, Miss Wilbrink gave us the following interesting statement:

One Chunnee seedling raised at the East Java Experiment Station and selected for propagation developed the habit of producing adventitious buds very freely around its nodes much after the fashion shown in the illustration, Fig. 9. This rendered the seedling worthless for commercial purposes and it was never spread to any extent. Superficial galls have been found on sticks of 247 B, but their occurrence on this variety is very rare.

Fig. 9. A specimen preserved in the museum in the East Java Experiment Station. A ring of adventitious buds surrounds each node.

Galls occur much more frequently on sticks of 66 B, but even on this variety they can never be said to be really numerous. You can usually find them in any field of this variety, but they do not occur on every stick by any means and are, as a rule, small and scattered, not clustered together.

A portion of a stick of P. O. J. 2714, bearing a great mass of adventitious buds on one side of a node was once sent to the Cheribon Station for examination. The buds were closely clustered approximating the arrangement of the eyes of a pineapple. This is the only case of proliferation in this variety which has come to my attention. I never saw a case of proliferation in P. O. J. 2725.

The Causal Factor Unknown

Various opinions and theories have been advanced to explain the production of galls by our canes, but none of these has, as yet, been supported with anything like adequate proof.

The general appearance of the galls, their position on the stem and their proliferating tendencies suggest at once the familiar crown galls: monstrosities which are caused by infection with a bacterial organism, *Bacterium tumefaciens.* To the best of our knowledge, however, crown galls are not known to occur on grasses or, for that matter, on any other monocotyledonous plant, but they do occur on a great many dicotyledonous plants. We have found bacteria in cane gall tissue and in stem tissue adjacent to galls, but we have not, as yet, demonstrated that they have any connection with the genesis of the galls.

All canes in Hawaii are more or less infested with acari, tiny mites or spiders which live under the leaf sheath and induce the formation of minute galls on the stem and sheaths. These tiny galls and the mites responsible for them have been known for many years in Hawaii and other cane-growing countries. It was quite natural, therefore, that we should suspect them of causing the development of a larger gall on occasion. When Mr. Moir sent badly galled canes to us from Maui in 1920 and we found them heavily infested with these mites, we at once concluded that the particular seedling cane in hand was extremely sensitive and reacted more strongly to the irritation caused by the mites than did the usual run of canes. In galled canes recently examined, however, we find that galls often begin their development and, in some cases, attain a considerable size, before the acari penetrate to their locations.

Proliferating galls were first noted at the Experiment Station on several of the U D seedlings and it was suggested by some observers that the galls were but an expression of the incompatibility of hereditary characters derived from two so unlike parents as Uba and D 1135. When a careful survey of all of the canes in the Station fields revealed galls on such varieties as Puaole, H 109 and Wailuku 1, however, this convenient hypothesis was seriously weakened.

To the best of our knowledge, galls have never been found on the Uba cane. They have, however, been found in varying numbers on many varieties of the big-stick race of canes. It might be argued then that gall production is a latent or suppressed character in these latter canes but becomes active in some of the varieties obtained by crossing these big-stick canes with the slender Uba. If this hypothesis could be substantiated, we could view gall production as simply an objectionable character to be eliminated by breeding.

While considering these interesting theories, we must not loose sight of the fact that much of the evidence recently obtained seems to indicate that these proliferating galls are the outward symptom of an infectious disease. Should this prove to be the case, then there is potential danger in the present situation and immediate and thorough investigation of the malady is imperative. We can easily devise and put into operation defensive measures that will be very effective now, but of little avail at a later date when the disease has become generally spread throughout the Islands. It is very important, therefore, that we determine, as soon as possible, the nature of the forces causing these galls on our canes. If they are inherent, we can breed them out of our cane: if they are extraneous, we must detect their character and take measures to protect our canes against them.

Adventitious Buds on Sugar Cane*

By Z. Kamerling

Translated by W. van H. Duker

A new organ of a plant, such as a leaf, bud or root, generally develops out of a tissue which has no definite function yet in the plant-organism, of which the cells have not yet assumed a specific shape in connection with the function to be performed. Such a tissue shows no, or a very minor, distinction between the various cells, which, in connection with their specific function, show a very different construction later on; they are, so to say, undeveloped. An artificial term for such tissue is meristem.

Every growing point both of the stem as well as the root consists of meristem. It does happen, however, that new buds or roots develop out of already fully developed tissue and in such cases we speak of adventitious growths.

Under normal conditions, no buds or roots grow on a leaf, the cells of the full-grown leaf are already shaped in a definite way in relation to some function which they have to perform either as tegumentary or chlorophyllus tissue. Yet, adventitious buds do sometimes develop out of already full-grown cells and grow to new plants as in the case of leaves cut from the Begonia and a few other plants. Adventitious roots grow on the bark of certain shrubs and trees if kept in moist soil and if adapted to be spread in this manner.

Especially, adventitious roots grow easily on many plants and, as a rule, the characteristics of forming adventitious roots and adventitious leaves indicates whether or not a plant can be spread by cuttings.

On a recent visit to Kremboong, Mr. Moquette called my attention to a peculiar growth on some cane varieties raised by him, and a closer examination proved that we were dealing here with a case of adventitious buds. Mr. Moquette kindly

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* From *Archief voor de Java Sukerindustrie*, Vol. I, pp. 57-61, 1900.

supplied me with sufficient material to study the younger development stages of this peculiar phenomenon.

Stalks which show this abnormality strongly have, besides the normal buds (which, as far as I investigated, were always present), some large lumps in the

Fig. 1. Illustration used by Kamerling and referred to in his text.

vicinity of some of the buds which, in some cases, grew apparently normal shoots. On closer examination, it turned out that the entire lump was covered with partly sprouted buds and sometimes with roots in between. These buds showed no regularity whatsoever in their arrangement. Some were normal (that is, the point was in the direction of the top of the stalk); others had a slanting position, and again, others were turned upside down. As soon as these buds begin to sprout, the young shoot grows in a vertical direction, upwards, just like normal shoots.

Fig. 1 is a reproduction of a photograph taken by Mr. Moquette and shows the lump. As far as I am aware, there is only one variety which shows this peculiarity badly and it happens to be a variety of no great importance commercially, the seedling No. 397. In this variety, this peculiarity occurs so frequently that in the comparatively small area of the seedling plot at Kremboong, several instances could be found without any difficulty, showing the peculiarity in no less degree than the stalk in Fig. 1. If the abnormality occurs in lesser degree, the small lumps are covered with fewer buds or sometimes with but a single bud.

Fig. 2 shows a piece of cane with, to the right of the normal bud, a lump covered with small scales and an adventitious bud.

Fig. 3 shows a similar adventitious bud which begins to develop while still attached to the stalk; we see here how the young shoot, while originally growing downwards to the right, already starts to grow upwards.

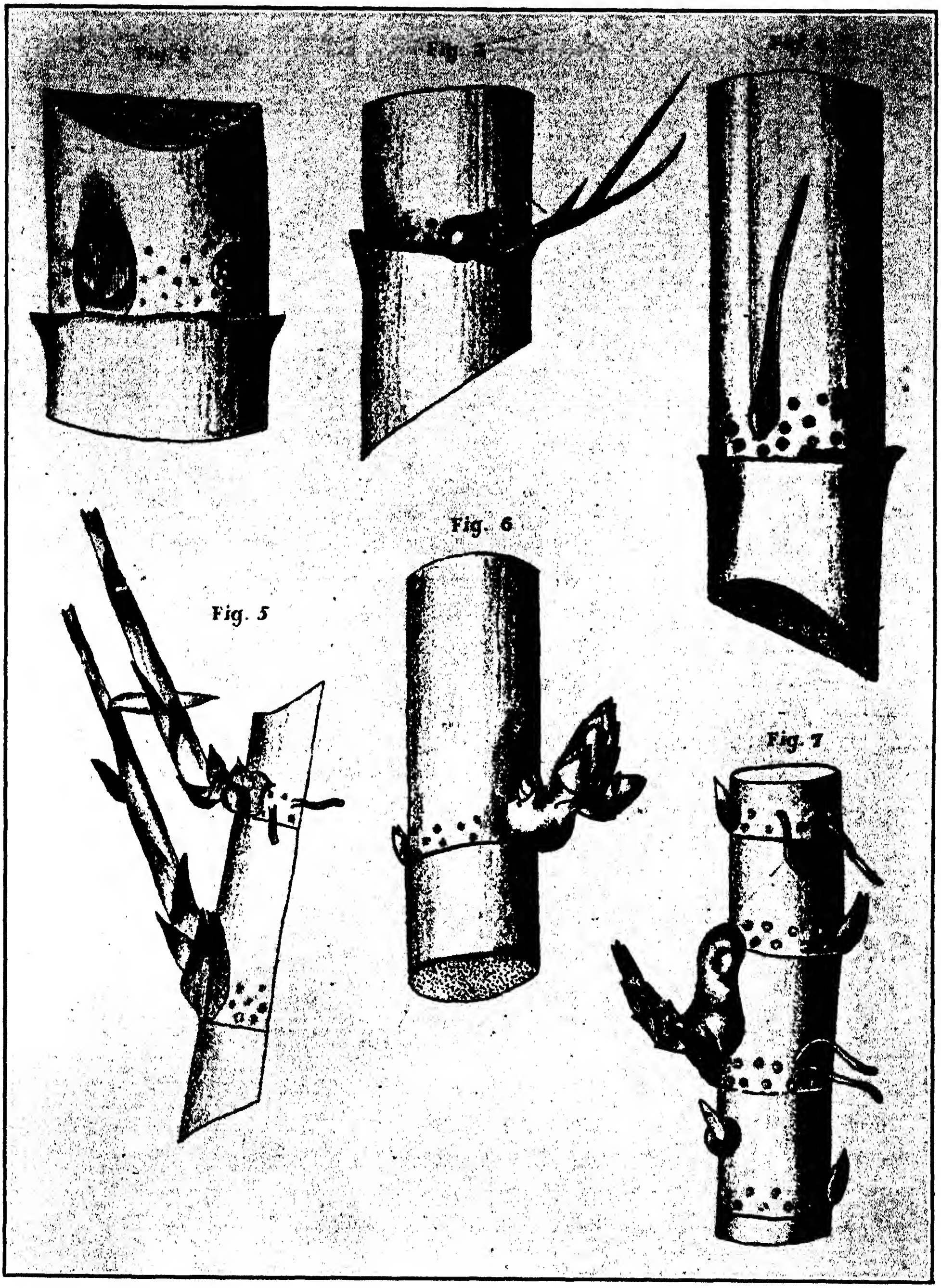
Fig. 4 shows a piece of cane with two such adventitious buds; in one case, we note a long scale and a groove such as occurs with normal buds. We can see in the illustrations of Figs. 2, 3 and 4, the adventitious growths not only differ from the normal buds in position but in shape as well. They are not regularly shaped buds, but more or less irregularly shaped lumps covered with irregularly placed smaller or larger scales.

Especially if we follow up the development, we note an irregular growth which, in some instances, grows out into a small shoot; in other cases, to comparatively normal buds which then continue to develop.

In Fig. 5, the upper one of the two sprouted buds is an adventitious bud as can be considered by observing the position in relation to the other buds on the same stalk; it has a kind of stem and is grown on the top of a small lump. The young shoot is entirely normal.

Fig. 6 shows a similar group of three adventitious buds, each by themselves. They are normal, but the place on the stalk, the grouping and the fact that they do not come directly from the stalk, but are placed together on a lump, indicates an abnormality.

The illustration in Fig. 6 is not of the seedling No. 397, but of No. 66, which shows this abnormality from time to time. The material of this variety I also collected at Kremboong. On lumps such as shown in Fig. 1, we always find both types of adventitious buds, both the normally shaped (which, however, show their characteristic as adventitious buds by their unusual position on the stalk and on top of a lump) and the irregular small lumps more or less covered with scales which, because they sometimes develop as shoots, are characterized as buds.



Figs. 2 to 7, inclusive. Illustrations used by Kamerling and referred to in his text.

The latter sprout but seldom, and, if they do (Fig. 3), the shoots are weak and poor, whereas the shoots from normally developed, adventitious buds grow just as well and forceful as normal buds on the same stalk.

Fig. 7 shows a piece of a stalk of the variety No. 397, which is also of interest. In the center of the three joints can be seen how the normal sprouting bud is pushed aside and forward by a large lump which has formed on the same joint. On this lump is another fairly normal adventitious bud in a rather advanced stage of development. On the lowest joint is a similar lump, as in Fig. 4, also covered with a large scale. Considering what might be the cause for the formation of such adventitious buds, I first took the lumps for wound tissue (callus). It often happens (not so much on coconut or palm trees, but very pronounced on mango trees) that the wound edge thickens and that the wound surface becomes slowly over-grown. On such callus adventitious growths are frequently found. and my first thought was that the lumps might be caused by small cracks in the stem and that the adventitious buds grew on top of these.

However, this idea proved to be wrong, because in examining the early stages of development of these lumps, I found the epidermis not touched and perfectly sound, and also that the tissue development begins in the interior of the stalk a little under the epidermis. So far, we do not know what causes these peculiar growths. The structure seems to indicate that it is a pathological case because in the consequent development stages, we find strong gum secretions in the vessels and between the cells, and gum formation does not occur in healthy cane plant tissue.

But a disease in the ordinary sense, it is not either, because the cane is otherwise perfectly healthy and the adventitious buds do at least sometimes develop in otherwise normal plants. Nothing has shown so far that this development of adventitious buds is in any way contagious, but it is heritable, as is quite common with similar abnormalities. Mr. Moquette stated that it recurs every year in this variety No. 397, and as far as I know, it has only been observed in the two before mentioned varieties, in No. 66 sporadically and in No. 397 frequently.

This appearance of adventitious buds cannot be mistaken for the peculiarity of two perefctly normal buds appearing in the place of a single bud. These double buds, which otherwise are very rare, I found in Cheribon and Muntok cane.

(H. P. A.)

Studies on the Pathological Nature of the Uba Node Gall Disease

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By C. C. Barnum

It is possible to report a few definite results of experiments with the so-called node gall disease of the U. D. varieties. In studies to determine the infectious or non-infectious nature of this disease, gall tissues or warts from U. D. 47 cane

badly affected with node galls were ground finely and the liquids extracted in a press exerting 1,000 pounds per square inch. Inoculations were made in healthy stalks of H 109, D 1135 and U. D. 14 canes. Controls with sterile tap water were made at the same time. In 26 days no galls were produced on the H 109 or D 1135 canes. Both the controls and inoculated stalks of U. D. 14 were equally affected with gall tissues at the close of 26 days' incubation period.

Healthy stalks of Uba and U. D. 47 cane growing at Manoa substation were inoculated with gall tissue from diseased U. D. 47 cane. Neither controls nor inoculated stalks developed galls in 26 days' incubation.

The conclusion drawn from these results is that node galls are not readily transmitted by direct contact. In other words the disease is not highly infectious under the conditions of the experiment, which were normal field conditions. On the other hand we have diseases of plants such as mosaic disease of cane and curly top of sugar beets which are not directly transmissible under usual field conditions, but which are nevertheless infectious when the proper insect vectors are present. Further studies are necessary to determine whether these node galls are in the class with abnormalities which are regarded as inherent genetic characters or constitute one of the diseases with insect vectors or other obscure means of transmission.

Progress Report on the Distribution of Cane Roots in the Soil Under Plantation Conditions

By H. Atherton Lee

In studying root rots in connection with the different types of Lahaina growth failure, it became necessary to understand the normal root system in order to be able to properly appreciate the nature and seriousness of root injuries. This led to the studies of root distribution in boxes reported in *The Hawaiian Planters' Record* for April, 1926 (Vol. XXX, No. 2, p. 267). It became apparent, however, that results under actual plantation field conditions would be much more satisfactory, so that a method of determining the distribution of roots was devised. As the studies have progressed it has become evident that the results are not only of value in connection with studies of root injuries, but they also have a value, in that exact knowledge of the distribution of the roots in the soil leads to a more intelligent understanding of the problems of tillage of the soil, cultivation, irrigation and fertilization.

Method of Determining Root Distribution in the Soil

Five representative stools of cane are selected, the cane is cut back, and the ground leveled to the junction of the stubble with the soil. A rectangular area is staked out extending 2½ feet on each side of the cane row to contain the five

stools to be studied. The rows being 5 feet apart, any roots of the plants being studied which extend beyond the sides of the excavation, are compensated for by the roots extending into the excavation from the cane rows on either side. An excavation is then dug in this staked area to a depth of 8 inches. In removing the soil from this area, the earth is thrown on a wire screen, ¼ inch mesh, and sifted through the screen; the cane roots are removed as they become separated from the soil on the screen. The roots from this 8-inch layer are collected, placed in a bag, and following this, the roots from the layers of soil 8 to 16 inches in depth and 16 to 24 inches in depth and so on are collected separately. The roots are then washed, oven-dried and weighed.

Fig. 1. Showing the excavation which is made to secure the roots of the cane, and the screen on the right through which the soil is sifted and the roots separated. Photograph by W. P. Alexander, of Ewa Plantation Company.

No stubble is included in the tabulation; where any appeared on the screen the roots were trimmed off and preserved, and the stubble discarded. The screen in use and the character of the excavation are shown in Figs. 1 and 2, which were made from photographs taken by W. P. Alexander, of Ewa Plantation.

To demonstrate the working of this method the following first few determinations of root distribution are presented.

Some of the Results With This Method

The first determination under this method was made on H 109 plant cane, 10½ months old, growing in Field G of the Waipio substation. This cane had had 28 irrigations and had received 275 lbs. of nitrogen and 175 lbs. of phosphoric acid, but no potash. The following results were obtained:

Fig. 2. This shows the screen more fully, on which the roots are separated from the soil after excavation. The paper bags into which the roots are placed are shown beside the screen. Photograph by W. P. Alexander, of Ewa Plantation Company.

TABLE I

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	135.23	70.14
8 to 16 inches	43.92	22.78
16 to 24 inches	11.34	5.88
24 to 30 inches	2.29	1.18
Totals	192.78	99.98

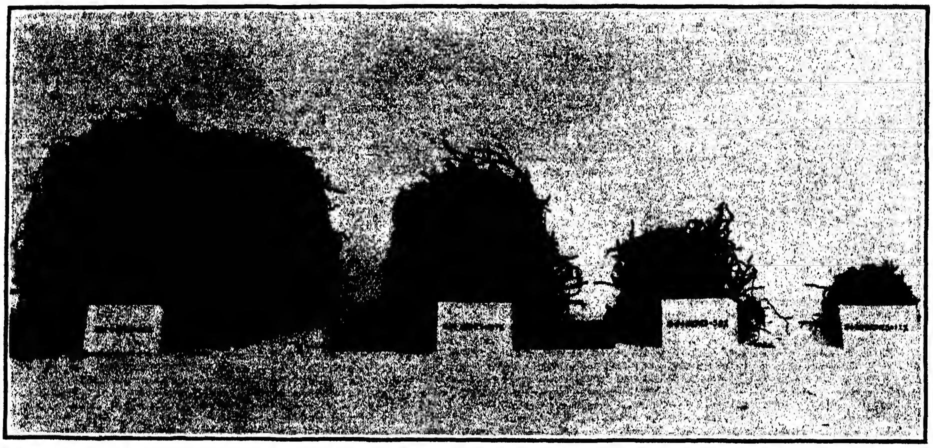


Fig. 3. Showing graphically the comparative masses of H 109 cane roots at different levels in the soil in Field G at the Waipio substation. The root mass in the topmost 8-inch layer of soil is a lighter brown color because of the greater proportion of small secondary actively feeding roots which are a lighter brown color than the older primary roots.

Fig. 3 shows these same results in a more graphic form.

A determination using five stools of Yellow Tip cane, 26 months old, unirrigated, from Field H 36 of Lihue Plantation Company, gave the following figures:

TABLE II

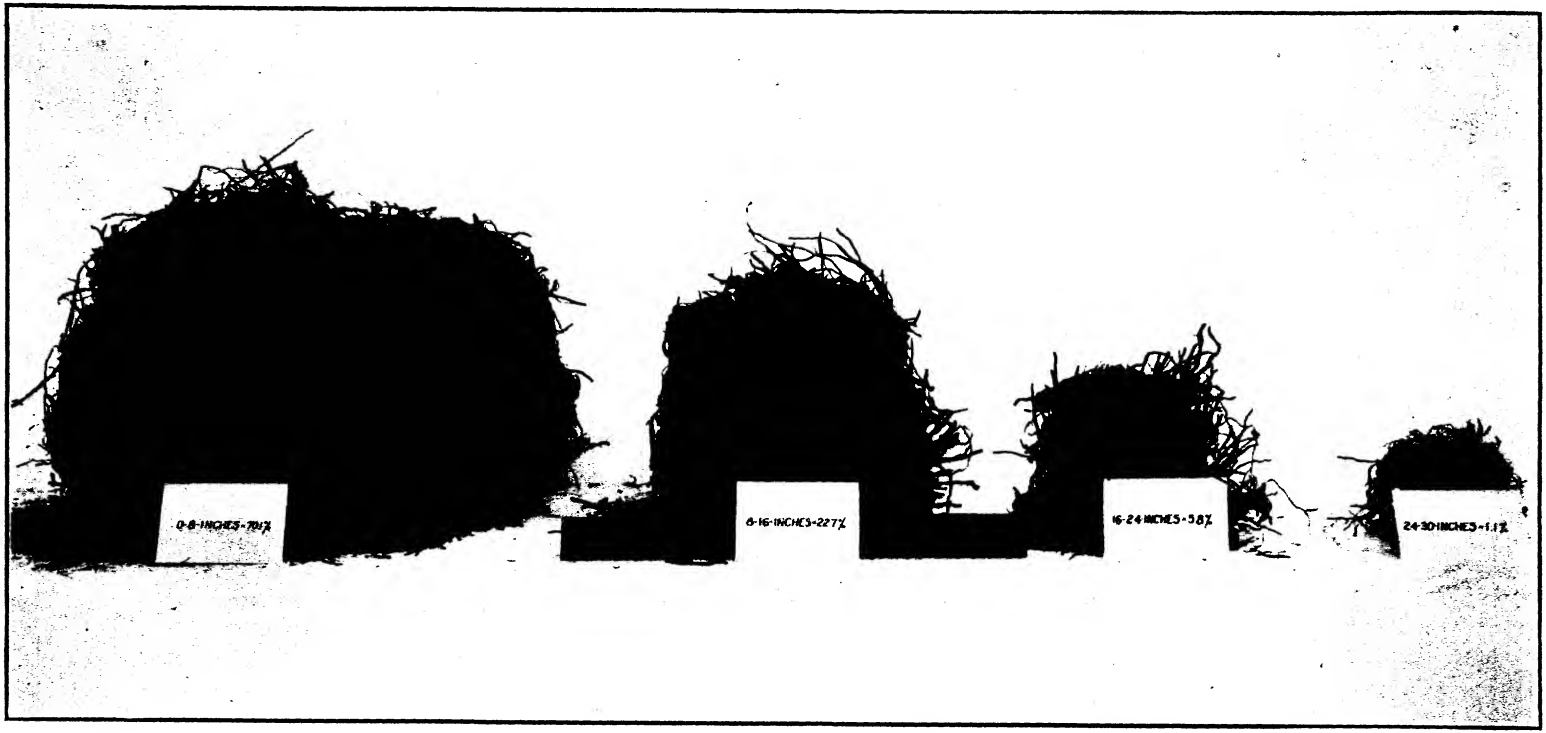
Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	72.5	70.0
8 to 16 inches	20.3	19.0
16 to 24 inches	8.7	8.0
24 to 32 inches	2.9	3.0
Totals	104.4	100.0

The soil was a loose loam, and the field yielded 35 tons of cane per acre.

Another determination, in Field H 41 of the Lihue Plantation Company, on cane of the same variety, age and treatment, which, however, yielded 75 tons of cane per acre, showed results as follows:

TABLE III

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	107.3	73.0
8 to 16 inches	26.1	18.0
16 to 24 inches	11.6	7.0
24 to 32 inches	2.9	2.0
Totals	147.9	100.0



Note: This insert shows the labels denoting the strata from which the several masses of roots were taken. In the smaller illustrations the labels are not clear, but in each case from left to right are shown the roots from the upper stratum down, corresponding to the tables in the text.

The soil in this case also was a loose loam, and the cane had not been irrigated.

It should be noted that, although the quantity of roots was much greater in the field yielding 75 tons of cane per acre than in the field with 35 tons per acre, the percentages of roots in the different levels were practically identical in the two cases. The only difference in the cane lay in the yields, as the variety, age, soil texture and agricultural practice were the same in both fields.

A determination was made on plant Yellow Tip cane, unirrigated, seven months old, in Field 28 of the Kilauea Sugar Plantation Company. The following figures were obtained:

TABLE IV

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	26.1	75.0
8 to 16 inches	5.8	17.0
16 to 32 inches	2.9	8.0
Totals	34.8	100.0

It is noticeable that although there was naturally a much smaller quantity of roots in the 7-months-old Yellow Tip than in the 26 months old cane, the proportion of the roots in the upper levels of the soil was only slightly greater in the younger cane. There are, of course, a number of variable factors other than the age of the cane to be considered in making a comparison with the roots from other plantations and fields.

The distribution of the roots of 11-months-old Badila cane was studied at the Kilauea Sugar Plantation Company. This was unirrigated plant cane in Field 29. The surface soil in this field was a thin loam, with the subsoil hard and compact. The results are shown below:

TABLE V

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	31.9	68.75
8 to 16 inches	8.7	18.75
16 to 32 inches	5.8	12.50
Totals	46.4	100.00

The proportion of roots in the upper levels of the soil for this Badila cane was very nearly the same as for the H 109 of about the same age at Waipio.

A determination was made at Ewa Plantation with plant H 109 cane, 16 months old, in Field 3C. This field yielded 64.48 tons of cane per acre. The soil was a very sticky black adobe, which made the isolation of the roots difficult. Undoubtedly some of the smaller roots were lost, but the relative loss would be about the same for each level. The figures are as follows:

TABLE VI

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	44.02	75.5
8 to 16 inches	11.06	18.9
16 to 24 inches	3.17	5.4
Totals	58.25	99.8

A second determination was made at Ewa, using second ratoon H 109 cane, 21 months old, in Field 13 E. The soil of this field, which yielded 113 tons of cane per acre, was a loose loam or alluvial silt, of very good physical quality to a depth of three or four feet. The results are shown below:

TABLE VII

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentages of Total Roots	
Kuakua	3.57	2.20	Topmost
1 to 2 inches	28.94	17.86	8 inches
2 to 8 inches	68.09	42.03	62.09%
8 to 16 inches	38.04	23.48	
16 to 24 inches	14.38	8.87	
24 to 32 inches	7.18	4.43	
32 to 40 inches	1.76	.98	
Totals	161.96	99.85	

In this last determination, which is further illustrated in Figs. 4 and 5, there are some outstanding features. This cane had a greater proportion of its roots in the lower levels of the soil than any previously studied. Probably this fact is correlated with the excellent physical structure of the soil to a considerable depth. There may be some significance in the correlation of this deep rooting and the high yield of the field. Mr. Alexander, agriculturist at Ewa, stated that the cane in this field was difficult to ripen off; this possibly may be due to the large proportion of the roots being deep in the soil, where it would require several months for them to dry out.

This was the first determination of root distribution in ratoon cane, and it was expected that some difficulty might occur in separating the roots of the present crop from those of previous crops. However, no roots of previous crops were encountered, so it seems evident that in 21 months the old roots have completely rotted away.

At the Waipio substation a comparison was made of the roots of five plants of Lahaina cane, 3 months old, and five plants of H 109, grown under similar conditions, but planted ten days later. The results are tabulated below:

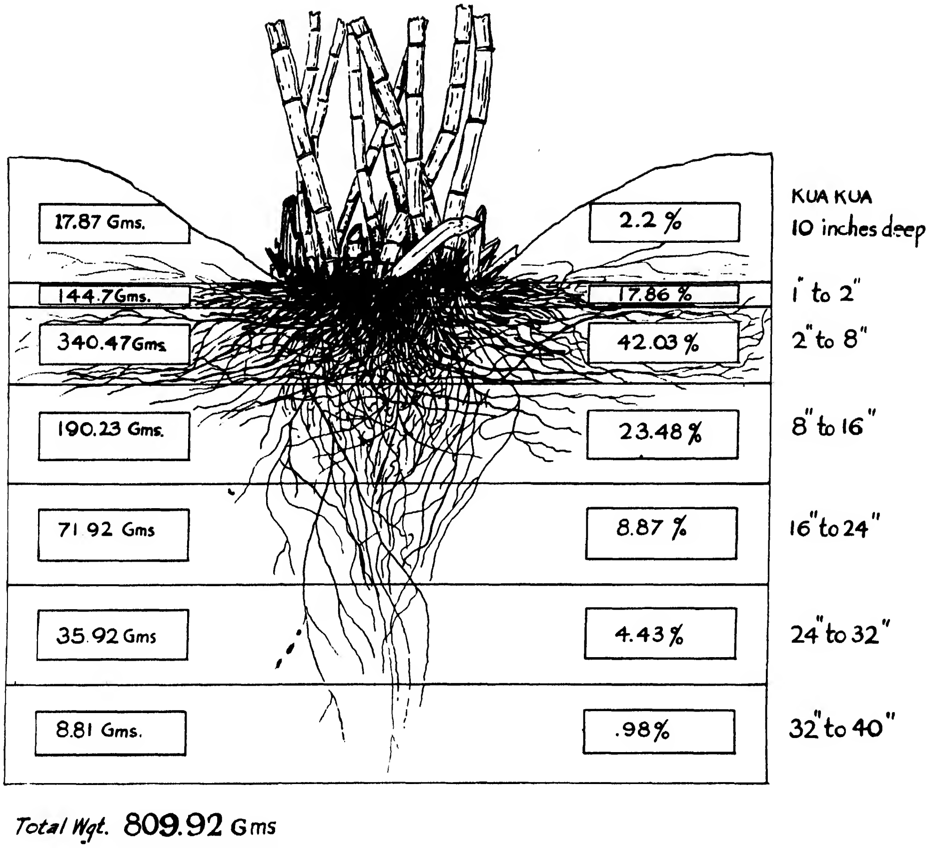


Fig. 4. Showing graphically the comparative masses of 21-month-old H 109 cane roots at different levels in the soil in Field 13-E at Ewa Plantation Company. The largest ratio of roots to the soil volume exists in the layer from 2 to 6 inches in depth, in this particular excavation. Drawing by J. A. H. Wilder.

TABLE VIII

Lahaina

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	13.51	87.86
8 to 16 inches	1.74	11.32
16 to 24 inches	0.12	.80
Totals	15.37	99.98

H 109

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	28.03	88.51
8 to 16 inches	3.21	10.13
16 to 24 inches	0.42	1.35
Totals	31.66	99.99

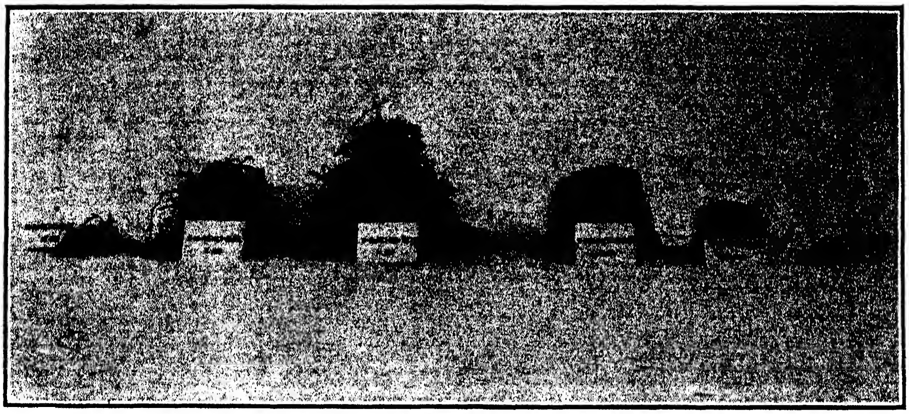


Fig. 5. Showing graphically the quantities of roots of 3-month-old Lahaina cane compared with the roots of H 109 of the same age under comparable conditions. There is only one-half the quantity of roots for the Lahaina cane as for the H 109, yet the proportions of roots in the different levels of the same are almost identical.

It is interesting that, in this comparison of the roots of 3-months-old Lahaina and H 109 at Waipio, the H 109 had more than 100 per cent more roots than the Lahaina, yet the percentages of roots in the different levels of soil were almost identical for the two varieties. This Lahaina cane was in an area which had previously suffered from one of the forms of Lahaina disease, and the roots were already abnormal, which would probably account for the unfavorable comparison of root weights with H 109.

Discussion

To the writer's knowledge such a method of determining quantitatively the distribution of the roots in the soil has not been developed previously for cane or for other crops.

A Large Proportion of the Roots is Above the 24-Inch Level in the Soil: The seemingly important result of these experiments, reporting as they do upon 45 plants, grown under very diverse conditions, is that in every case conservatively over 50 per cent of the roots were in the topmost eight inches of soil. It can be safely said, also, for these studies of cane in furrows, that more than 85 per cent of the roots are above the 24-inch level.

From the foregoing results, coupled with those obtained from the root-study boxes, which are not reported upon here, it seems evident that in young cane the proportion of roots in the upper levels of the soil is higher, but that as the cane grows older, the proportions of the root mass in the lower levels of the soil gradually increase. Even in the oldest cane studied to date, however, not more than 40 per cent of the roots were below eight inches in depth.

The distribution of the mass of cane roots in the soil under field conditions seems to be in the shape of a turnip, somewhat as shown in Fig. 5.

More Secondary Feeding Roots in the Upper Levels of Soil: The root masses in the upper layers of soil are usually lighter brown in color than the roots from the lower levels. The principal cause for this color difference results from the greater numbers of secondary roots in the upper layers of soil than in the lower levels; these secondary roots are light brown in color while the primary roots are usually black, so that the color difference usually seen between the different levels of soil has a significance, indicating that browner root masses have more secondary roots and usually greater areas of feeding surfaces.

More Cortex Rots of Roots in Deeper Levels of Soil: It was noted in all the determinations that roots in the deeper levels of the soil showed a much greater amount of rot in the outer layers, the cortex, than did the roots nearer the surface. Apparently, aeration in the upper levels of soil has a considerable influence in preventing cortex rots, and vice versa, the poorer aeration of the lower levels contributes to the occurrence of these rots.

Humus Returned to the Soil by Roots: The pushing of roots through the soil and their subsequent rotting away in subsequent crops, leaving channels, which we found commonly in the lower levels, must contribute somewhat to the better aeration of the soil. Organic matter also seems to have an influence in promoting aeration in the soil.

These experiments give a basis for calculating the amounts of humus returned to the soil by cane roots. Using 8,500 stools per acre as a basis for calculation, the H 109 cane with the greatest quantity of roots (Table I) would return about 1.85 tons of dry root material per acre, while the mature Yellow Tip with the smallest quantity (Table II) would return slightly less than one ton; these are figures for dry weights.

It seems evident that a workable method of studying the development and distribution of roots in the soil is available and comparisons of root systems under different soil environment and different methods of tillage, cultivation, irrigation and fertilization are now possible, which we propose to undertake.

Royden Bryan has assisted in the excavations of the roots in the field, and D. M. Weller and Z. A. Romero have made the weighings in the laboratory. Edward L. Caum has assisted greatly in the preparation of the manuscript.

The work recorded in the foregoing would have been impossible without the assistance of the plantations concerned, the Lihue Plantation Company, Ltd., the Kilauea Sugar Plantation Company, the Ewa Plantation Company, and the Waipio substation and appreciation is expressed to the personnel of these plantations for their ready and effective cooperation.

A Comparison of the Root Weights and Distribution of H 109 and D 1135 Cane Varieties

Excavations made at the Wailuku Sugar Company

By H. Atherton Lee

Using the methods outlined in a previous paper, root determinations for the variety D 1135 as compared with the variety H 109 were made in Fields 94 and 95 at the Wailuku Sugar Company.

Distribution of Roots of D 1135 in the Soil of Field 94

The part of the field in which the determinations were made is a very sandy loam to a depth of about 16 inches underlying which there is a stratum of pure sand for a depth of 5 to 6 inches and below that is a loose sandy loam.

The cane was 12 months old and had received 18 rounds of irrigation water, 200 pounds of nitrogen, 60 pounds of phosphoric acid and 60 pounds of potash per acre at the time of the excavation. The distribution of the roots by weight is shown in Table 1, which follows:

TABLE I

Distribution of the Roots of D 1135 in Sandy Soil in Wailuku Field 94

Depth in Soil	Weight in Grams of Roots for 5 Plants	Average Weight in Grams per Plant	Per Cent
Kuakua*	94.14	18.83	10.25
0 to 8 inches	448.64	89.73	48.85
8 to 16 inches	170.12	34.02	18.52
16 to 24 inches	108.15	21.63	11.77
24 to 32 inches	65.70	13.14	7.15
32 to 40 inches	31.52	6.30	3.43
	918.27	183.65	99.97

The root masses of D 1135, obtained from the different levels in the soil in Field 94, are shown in the photograph in Fig. 1.

This is the first determination of the roots of D 1135 which has been made. It was surprising to observe the percentage of roots in the layer from 0 to 8 inches in depth for this variety. In previous determinations, mostly with H 109, the proportion of roots in the layer from 0 to 8 inches in depth has run from 60 to 75 per cent of the total roots. D 1135 in this one instance seems to be more deep rooted than H 109, but further comparisons need to be made to confirm this difference. Another noteworthy feature is the large quantity of roots for this variety; only the highest yielding fields in previous determinations have yielded from 800 to 900 grams of roots for 5 plants.

* The Kuakua was from 10 to 13 inches in depth.

Fig. 1. Showing the root masses of D 1135 obtained from the different levels in depth in the soil in Field 94 at Wailuku.

Distribution of Roots of H 109 in Sandy Soil of Field 95

Across the road from Field 94, in Field 95 with a soil apparently identical to that of 94, 5 stools of H 109 plant cane, 11½ months old, were selected for root determinations. This H 109 cane had received 17 rounds of irrigation water, 200 pounds of nitrogen, 60 pounds of phosphoric acid and 60 pounds of potash per acre, at the time of the excavation. The distribution of roots of H 109 cane under these conditions, closely comparable to the conditions under which the D 1135 was growing, was then determined; the results follow in Table II.

TABLE II

Distribution of Roots of H 109 in Sandy Soil of Wailuku Field 95

Depth in Soil	Weight in Grams of Roots for 5 Plants	Average Weight in Grams per Plant	Per Cent
Kuakua*	22.19	4.44	3.65
0 to 8 inches	363.12	72.62	59.81
8 to 16 inches	147.72	29.54	24.33
16 to 24 inches	25.75	5.15	4.24
24 to 32 inches	27.22	5.44	4.48
32 to 40 inches	21.11	4.22	3.47
	607.11	121.41	99.98

The root masses of the above determination are shown in the photograph in Fig. 2.

The outstanding difference in the comparison between D 1135 and H 109 in these determinations, is the greater quantity of roots of the D 1135, amounting to about 50 per cent more than the H 109 by weight. D 1135 seems to be definitely more deeply rooted in this comparison than the H 109, there being 22.35 per cent

* The kuakua in this case was 6 to 8 inches in depth.

Fig. 2. Showing the root masses of H 109 obtained from the different levels in depth in the soil in Field 95 at Wailuku.

of the roots of D 1135 below the 16-inch level as compared to only 16.19 per cent below the same level for H 109. These results need to be corroborated by further comparisons of these varieties before such differences can be considered general.

In this case, the H 109 is more deep rooted than in any of the previous determinations for H 109. It is possible that the greater proportion of roots in the lower levels of soil in this case, is correlated with the sandy character of the soil which permitted aeration to greater depths in the soil than is the case with compact loamy soils.

Distribution of Roots of H 109 in Sandy Loam of Field 95

A second comparison was made between the H 109 in sandy soil, recorded in Table II, and H 109 in a more loamy soil higher up of the same field. The cane was approximately the same age and had received identical irrigation and fertilizer applications at the time of the excavations. The results follow in Table III:

TABLE III

Distribution of Roots of H 109 in Sandy Loam of Wailuku Field 95

Depth in Soil	Weight in Grams of Roots for 5 Plants	Average Weight in Grams per Plant	Per Cent
Kuakua	29.10	25.82	3.90
0 to 8 inches	409.36	61.87	54.96
8 to 16 inches	168.96	33.79	22.68
16 to 24 inches	69.31	13.86	9.30
24 to 32 inches	36.53	7.30	4.90
32 to 40 inches	31.55	6.31	4.23
	744.81	148.95	99.97

The results can be seen to be very similar for these two determinations, although there is a slightly greater quantity of roots in the loamy soil than in the sandy soil.

Weight of Roots is Correlated With Weight of Aerial Parts

It is interesting to make a comparison of the total root weights for these two determinations, with the weights of cane and cane tops from the same plants. The cane stalks and tops of the cane in sandy soil root determinations (shown in Table II) weighed 162 pounds as compared to a weight of 174 pounds for cane and tops of the H 109 in loamy soil. In this comparison there is a correlation between the quantities of roots and quantities of aerial parts. This correlation has been consistent in previous determinations so that it appears to be a definite conclusion that heavy root weights are correlated with heavy cane tonnage.

It is a pleasure to express appreciation to H. B. Penhallow and Neil Webster for their cooperation and interest in these studies.

A Comparison of the Root Distribution of Lahaina and H 109 Cane Varieties

Excavations made at the Hawaiian Commercial and Sugar Company

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By H. Atherton Lee

Using the methods outlined in a previous paper, root determinations for the variety H 109 as compared with the Lahaina variety were made in Fields 1 and 2 at the Hawaiian Commercial and Sugar Company. The results have an added interest in that they are the first ones obtained for hilled-up cane, all the previous determinations having been made for the roots of cane in furrows.

Distribution of the Roots of Lahaina Cane in the Soil of Field 2

The distribution of the roots was first determined for Lahaina ratoons, the previous crop of which had been harvested February 10 to 13, 1925; these ratoons were therefore 16 months old at the time of the determination. The present crop had received 181 pounds of nitrogen per acre and 63 pounds of phosphoric acid up to the time of these studies, according to Frank Broadbent. The soil in this field to a depth of 40 inches was a reddish loam which would appear fairly representative of the central Maui plain. This Lahaina cane was in fine condition with no indications of any growth failure. The distribution of the roots by weight is shown in Table I, which follows:

TABLE I

Distribution of Roots of 16-Months-Old Lahaina Ratoons in Field 2 at Puunene

Depth in Soil	Weight of Roots for 5 Plants in Grams	Average Weight per Plant in Grams	Per Cent
0 to 8 inches	354.26	70.85	19.09
8 to 16 inches	799.26	159.85	43.08
16 to 24 inches	434.84	86.97	23.42
24 to 32 inches	206.91	41.38	11.15
32 to 40 inches	60.26	12.05	3.24
Totals	1855.53	371.10	99.98

In the above determination the height of the hills, from the juncture of the cane with the soil, to the level of the furrows between the rows, was from 12 to 14 inches. This would limit the volume of soil in the topmost 8 inches, to a ridge less than 2½ feet broad at the 8-inch level and rising to an apex at the top of the hill. The ratio of roots to volume of soil would therefore be probably as high or higher in the uppermost 8 inches of soil, than in the level from 8 to 16 inches in depth.

Fig. 1. Showing graphically the root masses of 16-month-old Lahaina cane at different levels in depth in the soil.

The quantity of roots per stool of cane is very high in this determination, but because of the large excavation made (10 feet 10 inches long) the ratio of roots to the volume of soil is not unusual as compared to previous root determinations.

The root masses of the Lahaina cane in the different levels in depth in the soil are shown in Fig. 1.

Distribution of the Roots of H 109 in Field 1 at Puunene

Across the road from Field 2 where the root determinations were made on Lahaina cane, H 109 ratoons 15 months old, were growing in Field 1, in soil

similar in appearance to that in Field 2. The same fertilizer applications had been used and irrigation of both fields had been started within 20 days of each other. The H 109 was therefore under conditions fairly comparable to the conditions in which the Lahaina was growing, with the exception that the H 109 was one month younger than the Lahaina. The results from the determinations of roots for this H 109 cane follow in Table II.

TABLE II

Distribution of Roots of 15-Months-Old H 109 Ratoons in Field 1 at Puunene

Depth in Soil	Weight of Roots for 5 Plants in Grams	Average Weight per Plant in Grams	Per Cent
0 to 8 inches	240.71	48.14	12.86
8 to 16 inches	884.50	176.90	47.24
16 to 24 inches	474.91	94.98	25.26
24 to 32 inches	217.41	43.48	11.61
32 to 40 inches	54.81	10.96	2.92
Totals	1872.34	374.46	99.99

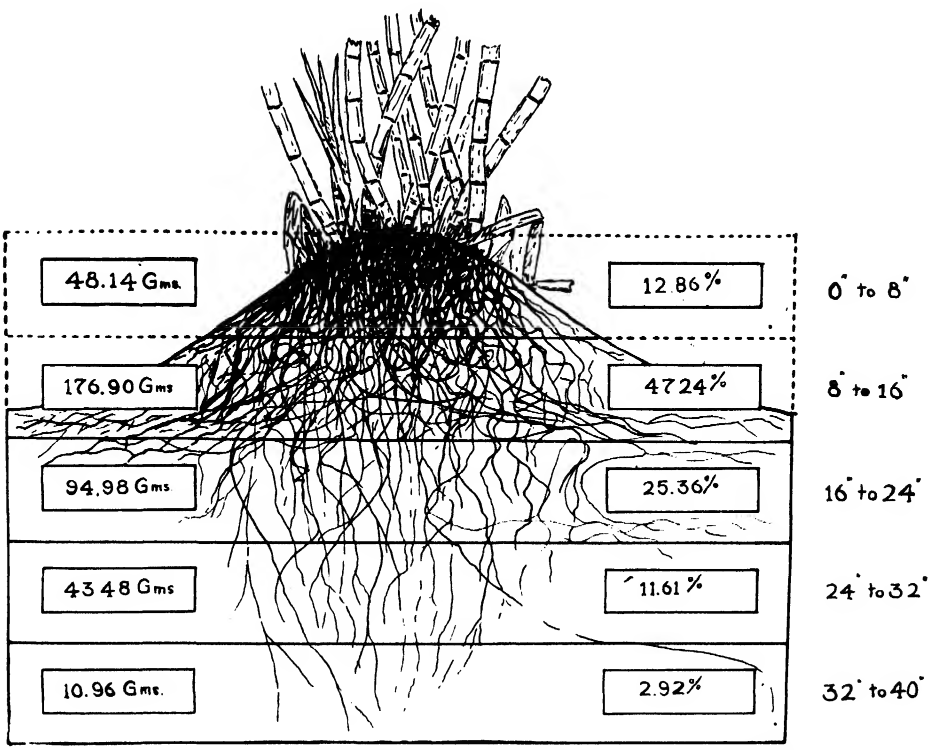

Fig. 2. A diagrammatic drawing by J. A. H. Wilder showing the distribution of the roots of H 109 under hilled-up conditions as found in Field 1.

The root masses of this H 109 in the different levels in depth in the soil are shown graphically in the photograph in Fig. 2.

The hills in the area from which these root excavations were made, were from 10 to 11 inches in depth from the juncture of the soil with the cane stalks, to the level of the furrows between the rows.

Comparison of Roots in Hilled-up Cane Versus Cane in Furrows

If one compares the root distribution of this hilled-up H 109 with previous results in which the H 109 has been in furrows, the outstanding difference is, that the largest percentage of roots is in the level from 8 to 16 inches in depth in the hilled-up cane, while in the cane in furrows the largest percentage of roots is in the topmost 8 inches.

Aeration of the soil has been stressed by many investigators as favoring root development and from the pathologist's viewpoint aeration might be expected to lessen fungus root rots. In hilled-up cane there would seem to be better aeration of the roots than in the case of the cane in furrows. This advantage, however, would possibly be more than balanced by the advantage to cane in furrows in that irrigation water, and nitrates in irrigation water, reach the greatest proportion of the roots of the cane when the cane is in the furrows than when the irrigation water runs between the rows in hilled-up cane.

Comparison of Root Distribution of Lahaina Versus H 109

There are no outstanding differences in this comparison of the roots of Lahaina and H 109. The H 109 is one month younger than the Lahaina, yet has a slightly heavier mass of roots. In the case of the Lahaina cane, 62.17 per cent of the roots are above the 16-inch level, while in the case of the H 109, 60.10 per cent are above the 16-inch level. This difference is so slight that one cannot say that one variety is markedly more deep rooted than the other.

Loss of Water and Nutrients from Cut Roots

Mr. Broadbent observed that the cut ends of roots from adjoining rows of cane, which extended into the area which had been excavated, would exude water or sap. This has been observed in other excavations since then, and there would appear to be a loss of water and nutrients from the plant from such cut roots sufficient to affect the plant unfavorably. This may be of interest in cultivation practices.

To Mr. Broadbent it is a pleasure to extend much of the credit for what appears in the foregoing studies.

The Determination of the Hydrogen Ion Concentration in the Cane Sugar Industry*

By Louis Baissac, F. C. S.,
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Introduction

When a cane juice is limed neutral to litmus it is still acid to phenolphthalein; this fact has been known for many years by the practical sugar house man; more

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lime must be added to obtain neutrality to phenolphthalein. As a result, the terms neutral, acid or alkaline to litmus, or neutral, acid or alkaline to phenolphthalein are of current use in the sugar house.

The practical man knows well that there is a difference when he makes use of one or the other indicators and this difference is shown at the defecation stage by a more or less rapid settling. The object of defecation is to obtain a clear and brilliant juice from the turbid and foul one as extracted by mills.

The turbidity of the juice is caused by the presence of colloid substances (pectins, gums, albuminoids, coloring matter, etc.) which are always more or less acid, strictly speaking, and which are held in suspension in the juice in a special state, named pseudo-solution. According to the nature of the colloids, this state is modified by the application of heat, the addition of an acid, of an alkali or base, lime for example. Colloids are either coagulated and separated from the juice in the form of a flocculent or precipitate or are dissolved. It has been observed that a juice neutralized to litmus, whether previously treated with sulphurous acid or not, usually settles down more rapidly than if neutralized to phenolphthalein. It will be stated later on that, strictly speaking, a juice neutral to litmus is in fact an acid juice, while a juice neutral to phenolphthalein is in fact an alkaline juice.

What is meant by neutrality, acidity or alkalinity in absolute terms? It is first of all necessary to define the word Ion.* Electrolytic particles in solution which carry with them a quantity of electricity positive for hydrogen or metals, or negative for non-metals or radicles are called ions. These particles carrying electric charges are free in solution and have the property of moving in any possible direction, hence the word Ion.

For example, hydrogen is present in acids in the state of hydrogen ion. The property of acids of turning blue litmus red is due to the hydrogen ion. The difference between ions and elements in the free state is that the former are always present in pairs, they are always in solution and their properties are quite different from those of the free elements.

Hydrogen as an element is a gas without any action on litmus; the hydrogen ion can exist only in aqueous solution and it turns blue litmus red. Hydrogen ions are present in acid, neutral as well as alkaline aqueous solutions, but they are much more numerous in acid solutions. The same volume of a tenth normal solution of caustic soda must be added to neutralize an equal volume of a tenth normal solution of hydrochloric or acetic acid, and yet these two acids are of different strength. The tenth normal solution of hydrochloric acid contains 3.65 grams of HCl per litre whilst that of acetic acid contains 6.0 grams of $C_2H_4O_2$ per litre. Ten cubic centimetres of a tenth normal caustic soda solution which contains 4 grams of NaOH per litre must be added to 10 c.c. of either of the tenth normal acid solutions for neutralization. How can it be accounted for, that the two acids are not of the same strength?

* The word Ion was given by Faraday, who borrowed it from the Greek; it means wanderer.

It has already been said that the property possessed by acids of turning blue litmus red is due to the hydrogen ion; the strength of the acid is due to the greater or smaller number of hydrogen ions present.

When an acid, a base or a salt is dissolved in water its molecules are divided into two parts carrying with them electric charges of opposite signs. For example: $HCl = H + Cl -$; $NaOH = Na + OH -$; $NaCl = Na + Cl -$. This phenomenon is called dissociation or ionization. All substances dissolved in water are not dissociated to the same degree. With the aid of special methods which will be mentioned later on it has been possible to determine that in a tenth normal solution of hydrochloric acid almost 95 per cent of the acid is dissociated in H ions and Cl ions, whereas in a tenth normal solution of acetic acid, only 1.3 per cent of the acid is dissociated in H ions and $C_2H_3O_2$ (acetic) ions. In the first case, there remains only 5 per cent of undissociated acid, whilst in the second 98.7 per cent of the acid remains undissociated.

When the caustic soda solution is added to the acid solution, the hydroxyl ion of the caustic soda combines with the hydrogen ion of the acid. When this combination is completed, another amount of the acid is dissociated, and a new addition of caustic soda solution again determines the combination. This goes on until all the acid is dissociated. If the reaction is made with litmus as indicator, the solution will remain red until the very moment when the last trace of acid will have been dissociated and will have combined with the caustic soda; then only the solution will turn blue, showing that there is no more dissociated hydrogen to combine with the hydroxyl of the caustic soda; the blue color is then due to the free hydroxyl left in the solution.

It is therefore obvious that by titration with caustic soda, the total amount of hydrogen ions contained in the acid is determined, and not the amount of free hydrogen ions existing at a given moment, i. e., the sum of actual and virtual ions or in other words, ionized hydrogen, and hydrogen that can be ionized or potential acidity. On the other hand, by the determination of hydrogen ions, the actual strength only of the acid is determined, this strength depending upon the degree of ionization.

It has long been wondered at why all acids do not invert cane sugar or sucrose to the same extent for a given concentration and temperature. The answer is in their degree of dissociation. The comparative inverting power of acids is to a certain point a measure of their dissociation or ionization.

As it may be seen, there is therefore an essential difference between total or potential acidity which may be determined with a standard alkali and active acidity caused by dissociation in positive hydrogen ions and in negative ions.

Meaning of the Term pH

Total acidity and active acidity are expressed in terms of normality. By titration with an alkali, the total amount of acid present is determined whilst in measuring the activity, only dissociated hydrogen ions are determined, and this quantity of dissociated hydrogen ions is expressed in terms of normality. Sorensen calls cH, the concentration of hydrogen-ions per litre. If the amount present is

one gram per litre, cH will be equal to 1.0. If the concentration is 100 times less, that is to say, 1 gram per 100 litres, cH = 1/100, which may be written 10^{-2}; 1 gram in 10,000 litres will be cH = 1/10,000 or 10^{-4}, etc. As very small fractions or negative exponential values (such as —4, or —7, etc.) are inconvenient, Sorensen called pH, the numerical value of the negative exponent of 10.

$$cH = 10 - pH = \frac{1}{10\ pH} \text{ or } pH = \log 10 \frac{1}{cH},$$ which means that pH is equal to the logarithm to the base 10 of the reciprocal of the hydrogen ion concentration expressed in grams per litre; or in other words, the common logarithm of the volume in litres containing 1 gram of hydrogen.

All substances in solution are more or less ionized. Even pure water follows this rule. The formula of water, H_2O, may be written HOH and HOH = H + OH. In that case, there is an equal amount of positive free hydrogen ions H and negative free hydroxyl ions OH. At normal temperature, there are 1/10th of a million gram molecule of hydrogen ions in 1 litre of water: 1/10000000 or more simply 1×10^{-7} gram molecule. Therefore water is 1×10^{-7} normal as regards hydrogen ions, and 1×10^{-7} normal as regards hydroxyl ions, the total ionization being 1×10^{-14}. When neutral salts are dissolved in water, this ratio is not altered, but when an acid is dissolved, there is H and negative free hydroxyl ions OH. Inversely, when a base is dissolved there is an excess of hydroxyl ions on hydrogen ions. However, whatever may be the quantity of H ions present, there is always a sufficient quantity of OH ions to maintain the above relation or ratio of 10^{-14} for the total quantity of ions. If the H ion concentration of a solution is 1×10^{-6}, normal or pH = 6, the hydroxyl ion concentration (OH) will be 1×10^{-8} normal or pH = 8.

Sorensen, the originator of this method, took it for granted that pH up to 6.99 indicates acidity; 7.0 will indicate absolute neutrality, i. e., the pH of pure water and figures above 7.0 will mean alkalinity. In other words, the lower the figure below 7.0, the higher the active acidity of the solution and the higher the figure above 7.0, the higher its active alkalinity.

For example, let us consider a cane juice as extracted by mills, this juice after sulphitation, then limed to normal defecation point and slightly alkaline to litmus; lastly filter press juice from muds difficult to filter and limed to slight alkalinity to phenolphthalein (which is met with unfortunately too often in practice). Let us suppose 5.6 to be the pH of the mill juice; 3.6 that of the sulphured juice which becomes 6.8 after liming and the filter press juice to be pH 8.8. The sulphur juice will be more actively acid than the mill juice; the limed juice will be almost neutral and the filter press juice will be very alkaline. These figures have at the same time intrinsic values; the sulphured juice will be 100 times as actively acid as the mill juice, and the latter will be about 16 times as actively acid as the limed juice; this limed juice will be only 1.6 times as actively acid as water which means almost practical neutrality. The filter press juice will be alkaline: 63 times more alkaline than pure water. These numerical values are explained as follows: the difference between log 5.6 and log 3.6 is log 2.0. The natural number whose logarithm is 2 is 100. In the same way, the difference between 6.8 and 5.6 is 1.2;

15.8 is the natural number whose logarithm is 1.2. Between 7.0 and 6.8 there is but a difference of .2 and the natural number corresponding to log .2 is 1.58. Lastly the difference between 8.8 and 7.0 is 1.8, the log of 63.1.

It is essential to note that a difference of 2.0 in the pH of two solutions means that there is in one of them 100 times more or 100 times less ions than in the other, whilst a difference of 1.0 means that the hydrogen ion concentration is only 10 times more or 10 times less and if the difference is only .1 the hydrogen ion concentration differs but by 1.26 times.

Methods for the Determination of pH

There are several methods for the determination of the hydrogen ion concentration or pH, but the two more commonly employed are the electro or potentiometric, and the colorimetric. For current laboratory or industrial needs, the colorimetric method is quite sufficient although not so accurate; it is much simpler and can be made use of by anybody in the sugar house; it is almost as simple as the use of litmus paper. The potentiometric method will not be described in this bulletin.

The colorimetric method is based upon the change of color or shade which takes place when solutions of different indicators are submitted to gradual changes in pH. Most indicators show a maximum change for a small range in the pH.

Indicators (such as litmus, methyl orange, phenolphthalein, etc.) are weak organic acids (or bases) liable to form salts. In solution these indicators are dissociated exactly as mineral acids or salts and their anions (or negative ions) differ in color from the dissociated acids. In an alkaline medium, the indicator forms a salt totally dissociated. In an acid medium, the free acid only is present and is but very slightly dissociated, this dissociation being reduced to a minimum if there is an excess of H ions present. At intermediate stages between these two extremes, there are mixtures of salts and undissociated acid and consequently mixtures of colors. For example, let us consider the case of litmus, to which everyone in the sugar house is familiar; undissociated azolitmin, (the acid of its coloring matter) is red in acid solution whilst the neutralized and totally dissociated salt is blue. Between these extremes, there are mixtures of red and blue—all the purple shades—everyone corresponding to a certain pH. When half the coloring radical is dissociated, the colors are in equal proportions, and the slightest change in the pH will show a rapid change in the resulting shade. All the indicators behave similarly. This is the basis of the method of the determination of pH. (When the indicator is a weak basis the phenomena are the same, but reversed.)

The following is a list of a few indicators with their extremes: the first figure is the pH at which dissociation starts and the second that of total dissociation. A pH lower than the first figure does not modify the initial color, and in the same way a pH higher than the second one.

Name of the Indicator	Concentration Grs. Per Cent c.c.	Change of Color	Limits of pH
Bromophenol blue	0.04	from yellow to blue........	3.0— 4.6
Methyl orange	0.02	" red to yellow........	3.1— 4.4
Methyl red	0.02	" red to yellow........	4.4— 6.0
Bromocresol purple	0.04	" yellow to purple......	5.2— 6.8
Bromothymol blue..........	0.04	" yellow to blue.......	6.0— 7.6
Litmus (azolitmin)	....	" red to blue..........	4.5— 8.3
Phenol red	0.02	" yellow to red........	6.8— 8.4
Cresol red	0.02	" yellow to red........	7.2— 8.8
Phenolphthalein	0.05	" colorless red	8.3—10.0

It will be noticed that the indicator the more commonly employed in the sugar factories in Mauritius, litmus, is the one with the wider range, which makes it the less sensitive.

The *modus operandi* for the determination of the pH of a solution by the colorimetric method is as follows: —10 c.c. of the solution are measured in a 16 m/m diameter test tube* to which are added from 0.3 to 0.5 c.c. of the suitable indicator; the same volume of the solution is measured in another test tube; but in this one no indiçator is added; the two tubes are placed in a "comparator," one near the other. A test tube filled with pure water is placed in front of the tube containing the solution with the indicator and in front of the other is placed the tube filled with a "buffer" solution of a known pH, colored with the same indicator; when the shade of the solution is the same as that of the buffer, the solution is of the same pH as the buffer.

The most convenient buffer is the one prepared by the "British Drug Houses, Ltd.," of London, and known as the B. D. H. Universal buffer solution. It is composed of a salt (Dr. E. B. R. Prideaux's formula) of which a certain weight is dissolved in one litre of pure neutral water.† The pH of the solution is constant; by the addition of known volume of 1/5 normal solutions of hydrochloric acid or caustic soda, the pH of the original B. D. H., buffer solution is modified to the required pH. A set of buffer solutions with a constant difference of 0.2 pH is prepared, the suitable indicator is added accordingly and the standards so obtained will keep pretty well in sealed tubes.

A convenient comparator is the one described by Mansfield Clark (The determination of hydrogen ions, p. 70, 1922). It may be made from a block of wood. Six deep holes just large enough to hold ordinary test tubes are bored parallel to one another in pairs. Adjacent pairs are placed as close to one another as can be done without breaking through the intervening walls. Perpendicular to these holes and running through each pair are bored smaller holes through which the test tubes may be viewed. Before use, it is well to paint the whole block and especially the holes, a non-reflecting black.

* Test tubes must be of first quality, neutral, colorless glass; ordinary glass gives up alkalinity even to pure water and is objectionable.

† Distilled water is usually acid, and the pH of natural waters—spring, river or well—is very variable. Mare-aux-Vacoas water, for instance, is alkaline; pH 8.5—8.6. It is very easy to neutralize any water to pH 7.0.

Application of the Colorimetric Method

The colorimetric method for the determination of pH in the cane sugar manufacture was first applied by H. F. Brewster and W. G. Raines, Jr., in Louisiana, and the results obtained were presented by the authors at the meeting of "The American Chemical Society" held in Birmingham, Ala., U. S. A., in April, 1922—Division of Sugar Chemistry.

The authors, instead of using test tubes and comparator, employed the drop plate method; they added one drop of the appropriate indicator solution to three drops of the test liquid contained in the depression of a porcelain spot plate. The color thus obtained was matched with similar spots made by adding one drop of the same indicator to three drops of a standard buffer.

The comparison with buffers is valuable especially when the solution to be tested has a pH which does not permit of the use of bromothymol blue.

For quick and approximate determinations (+ 0.1 pH), the comparison with Clark's color chart is good enough. Mr. R. G. W. Farnell, research chemist of the British Empire Sugar Research Association, applies it as follows:

To 2 c.c. of juice or 1 c.c. of syrup (Clairce) measured in a test tube and diluted to 10 c.c. with neutral water (pH 7.0), (.@), 0.3 to 0.5 c.c. of the required indicator are added; the tube is placed in the comparator and the color is compared with that of the chart for the indicator employed.

Dilution does not modify much the pH, particularly for neutralized juices and raw syrups (Clairces), in which cases the determination of the pH with bromothymol blue and the match with the color chart is accurate enough.

When dealing with mill and sulphured juices, acidified syrups (Clairces) and limed filter press juices, the pH is not much modified by dilution, but matching is sometimes difficult because the colors do not agree exactly; the operator must use some imagination and discretion to judge of the difference of colors and find the agreement between the shades.

Practical Considerations and Results Obtained

It has already been seen that a juice neutralized to litmus settled more quickly than when neutralized to phenolphthalein. This is due to the fact that in the first case, the pH of the juice is nearer to the optimum at which colloids settle readily. When lime is gradually added to a sulphured juice, pH (3 to 4), it combines with the sulphurous acid to form calcium sulphite and with the acids pre-existing in the juice; as the pH increases, that is to say, as the acidity is lessened, the colloids coagulate until a point is reached when they rapidly settle, leaving a clear, supernatent liquid. According to research made in other cane countries, and observations made this year in Mauritius by Farnell and the writer, this optimum pH is very near 7.0. If the amount of lime is increased, the colloids expand, are more hydrated and bulky, the more so as the pH will be higher. As phenolphthalein begins to show a pink shade at pH 8.5, if this indicator is made use of, it is obvious that the settling will be slower and the colloidal deposit more bulky than in the case of litmus. X

In Mauritius the juice is first sulphured, then limed. The man in charge of the liming, locally called "sucrier," adds lime to the juice up to a slight alkalinity to

litmus. He takes in a glass or test tube a sample of the juice so treated, and observes the flocculent precipitate formed. According as the precipitate settles more or less rapidly, as it is more or less bulky and as the supernatent liquid is more or less clear, he is satisfied with the liming point. If not, he adds some more lime in the tank if he considers it necessary; on the other hand, if he thinks too much lime has been added, he will put less in the following tank. This man in charge is unaware that he has found out the optimum pH of that particular juice. This figure seems very constant for a factory dealing with the canes of the same locality. If the man in charge is clever he will stick to the optimum pH and the resultant clear juice will be satisfactory. He will use litmus paper only occasionally.

There are cases when this *modus operandi* is defective—with very dark colored cane, for instance. The man in charge is puzzled and is inclined to use too little lime because of the dark color of the supernatent juice. In such cases, the determination of the pH with bromothymol blue may help. At all events, the determination of the pH permits of obtaining a more regularly clear juice and does away with the cleverness of the "sucrier."

In 1923, the writer was asked to follow the application of the Bach process at Highlands; he noticed that the filtration of the treated syrup was irregular and sometimes very difficult. Regular good filtration was obtained when he applied the method of the determination of the hydrogen ion concentration—pH 6.8 to 6.9—litmus was not reliable; judging by the settling of the precipitate was impossible—for the precipitate was composed almost exclusively of calcium sulphite and a very small percentage of colloids. If sulphitation was stopped when litmus showed a light blue shade, inversion occurred, and when phenolphthalein was employed as indicator, filtration was almost impossible. The determination of the optimum pH solved the difficulty.

Conclusion

Amongst many others there are two important points to be watched during the manufacture of sugar: excess of active acidity, causing the inversion of sucrose, and excess of active alkalinity which decomposes reducing sugars.

Inversion is a cause of loss dreaded by the practical man; destruction of reducing sugars is also a cause of loss which should be dreaded, for any destruction of these sugars means the retention of about an equal amount of sucrose by salts in final molasses, according to Prinsen Geerligs' unquestionable theory.

There is a rather narrow range of pH between the beginning of inversion and the destruction of reducing sugars; the more so when the sugar solution is of a low specific gravity and at a high temperature; the determination of the hydrogen ion concentration at the successive stages of the manufacture of sugar enables of their prevention.

(W. R. M.)

Sugar Prices

96° Centrifugals for the Period June 16, 1926, to September 15, 1926

Date		Per Pound	Per Ton	Remarks
June	16, 1926......	4.18¢	$83.60	Cubas.
"	17...........	4.16	83.20	Cubas, 4.14, 4.18.
"	18...........	4.14	82.80	Cubas.
"	22...........	4.11	82.20	Porto Ricos.
"	25...........	4.08	81.60	Cubas.
"	29...........	4.16	83.20	Cubas, 4.14; Porto Ricos, 4.18.
"	30...........	4.18	83.60	Porto Ricos.
July	7...........	4.195	83.90	Cubas, 4.21; Philippines, 4.18.
"	8...........	4.16	83.20	Cubas, 4.14, 4.18.
"	9...........	4.14	82.80	Cubas.
"	14...........	4.11	82.20	Cubas.
"	15...........	4.095	81.90	Cubas, 4.11, 4.08.
"	16...........	4.11	82.20	Cubas.
"	19...........	4.14	82.80	Cubas.
"	21...........	4.125	82.50	Cubas, 4.14, 4.11.
"	22...........	4.125	82.50	Philippines, 4.14; Cubas, 4.11.
"	23...........	4.14	82.80	Philippines.
"	26...........	4.18	83.60	Cubas.
"	27...........	4.195	83.90	Porto Ricos, 4.18; Cubas, 4.21.
"	28...........	4.18	83.60	Cubas.
Aug.	3...........	4.21	84.20	Cubas.
"	4...........	4.225	84.50	Cubas, 4.21; Philippines, 4.24.
"	5...........	4.21	84.20	Cubas.
"	9...........	4.27	85.40	Cubas.
"	11...........	4.225	84.50	Cubas, 4.24, 4.21.
"	16...........	4.24	84.80	Cubas.
"	24...........	4.22	84.40	Cubas.
"	25...........	4.21	84.20	Cubas.
"	27...........	4.27	85.40	Cubas.
Sept.	8...........	4.33	86.60	Cubas.
"	10...........	4.38	87.60	Cubas, 4.36, 4.40.
"	13...........	4.43	88.60	Porto Ricos.
"	15...........	4.40	88.00	Philippines.